TABLE OF CONTENTS

Address from the President of the IChO-2007

Dear friends!

The 39th International Chemistry Olympiad is in the past. What will you remember from July 2007? I really hope your memory recalls bright moments of the Opening and Closing Ceremonies, nice sites of Moscow, unforgettable time spent with many old and new friends. And of course, mentors will remember intriguing discussions of examination tasks, whereas students – huge efforts to solve them. I am really sure everybody agrees that the 39th IChO became an important step in the development of International Chemistry Olympiads and science education as a whole.

Many organizations and individuals significantly contributed to the 39th IChO success. I have a pleasure to thank the Ministry of Education and Research of Russian Federation and personally the Minister A. Fursenko for serious attention to the Olympiad, which we felt at every stage of preparation.

I address warmest words of gratitude to the Rector of Moscow State University, Full Member of Russian Academy of Sciences, Professor V. Sadovnichy. Organization of IChO required coordinated efforts of various divisions and services of the Moscow University, and we always got positive and benevolent response and readiness to help.

MSU Chemistry Department was the host organization of the 39th IChO, and thus delegated the maximal number of members to the Science Committee, as well as to the working groups which assisted during examinations and other Olympiad events. I thank everyone who contributed to the IChO. Without your enormous efforts, dedicative work and high professionalism, this Olympiad would never have come true.

We are extremely grateful to all the sponsors. Their donations allowed conducting the Olympiad at a high technical level. I am absolutely sure that it was a very useful investment in the growth of talented young people from all over the world, and the companies will gain numerous benefits in future.

It is my pleasure to thank all the students for excellent participation in IChO and following the standards of fair competition. My congratulations on excellent results achieved at quite complicated sets of practical and theoretical problems. And of course I am very grateful to all mentors, scientific observers, guests and guides. Your positive attitude, creativity and enthusiasm produced warm and friendly atmosphere which we all experienced throughout the Olympiad.

I really hope that all of you enjoyed the time spent in Moscow, and at MSU Chemistry Department, in particular. As the Dean of Chemistry Department and President of the 39th IChO I have a pleasure to say to all the participants: You are very much welcome back!

With best wishes

Valeriy V. Lunin
Professor
Dean of MSU Chemistry Department
Full Member of Russian Academy of Science
President of the 39th IChO

OVERVIEW of the ICHO-2007

Period	July 15-24, 2007
Venue	Chemistry Department, M.V. Lomonosov Moscow State University
Official Airports	Sheremetievo International Domodedovo International
Students Location	Hotel 'Olympiets', 5 km away from Moscow
Mentors, Scientific Observers and Guests Location	Hotel "Holiday Inn Sokolniki"
Host Organization	Chemistry Department, M.V. Lomonosov Moscow State University
Supported by	Government of Russian Federation Ministry of Education and Science, RF M.V. Lomonosov Moscow Sate University
Main Sponsors	"Basic Element" Company, "Lukoil"-neftekhim Vladimir Potanin Foundation
Sponsors	Norilsk Nickel; DuPont; BASF; Schlumberger; ESN Group of Companies; Procter and Gamble; JSC "Sibur"; Eurocement Group; Tokyo Boeki Ltd., Renova Group of Companies; Helios IT-Operator; Analytik Jena; Institute for New Carbon Materials; Russian Chemist Union; Bruker Companies; Oil Transporting JSC "Transneft"; Publishing House "Drofa"; Bayer MaterialScience; BP Traiding Ltd.; Dr. Barbara Mez-Starck Foundation; Lhoist Group; ACD/Labs; BioChemMac Group of Companies

Information Sponsors	Publishing holding “Career-Press”; “Chemistry and Life”; The Chemical Journal; “Nanometer” portal

Participation		
	Countries	67 participating, 1 observing (Nigeria), new participant – Moldova
	Students	256
	Mentors	132
	Scientific Observers	44
	Guests	15
Results		
	Gold Medals	31
	Silver Medals	56
	Bronze Medals	71
	Honorable Mentions	10
Operational Stuff		230
	Organizing Committee	20
	Science Committee	34
	Secretariat	8
	Technical Committee	19
	Lab Instructors	24
	Lab Assistants	21
	Spectrophotometer Operators	26
	“Catalyzer” team	15
	Guides	72

PARTICIPATING COUNTRIES

Country	Code		Country	Code
Argentina	ARG		Kyrgyzstan	KGZ
Armenia	ARM		Latvia	LVA
Australia	AUS		Lithuania	LTU
Austria	AUT		Malaysia	MYS
Azerbaijan	AZE		Mexico	MEX
Belarus	BLR		Moldova	MDA
Belgium	BEL		Mongolia	MNG
Brazil	BRA		Netherlands	NLD
Bulgaria	BGR		New Zealand	NZL
Canada	CAN		Norway	NOR
China	CHN		Pakistan	PAK
Chinese Taipei	TPE		Peru	PER
Croatia	HRV		Poland	POL
Cuba	CUB		Portugal	PRT
Cyprus	CYP		Romania	ROU
Czech Republic	CZE		Russian Federation	RUS
Denmark	DNK		Saudi Arabia	SAU
Estonia	EST		Singapore	SGP
Finland	FIN		Slovakia	SVK
France	FRA		Slovenia	SVN
Germany	DEU		Spain	ESP
Greece	GRC		Sweden	SWE
Hungary	HUN		Switzerland	CHE
Iceland	ISL		Tajikistan	TJK
India	IND		Thailand	THA
Indonesia	IDN		Turkey	TUR
Iran	IRN		Turkmenistan	TKM
Ireland	IRL		Ukraine	UKR
Israel	ISR		United Kingdom	GBR
Italy	ITA		United States	USA
Japan	JPN		Uruguay	URY
Kazakhstan	KAZ		Venezuela	VEN
Korea Republic	KOR		Vietnam	VNM
Kuwait	KWT			

Nigeria – observing country (first year)

PROGRAMS

Students and guides

July 15 Sunday	Whole day	Arrivals, Registration at Chemistry Department, MSU Transfer to Olympiets Hotel
	18.00-19.00	Welcome Dinner, Olympiets
July 16 Monday	9.00	Buses depart to the Opening Ceremony, MSU
	11.00-13.00	Opening Ceremony, MSU *Intellectual Centre – Fundamental Library*
	13.00-15.00	Welcome Reception, MSU *Main Building*
	15.00-18.00	Moscow City tour
	18.00	Transfer to Olympiets
	20.00-24.00	Disco
July 17 Tuesday	9.00	Buses depart to the North Shipping Terminal
	10.00-17.00	Boat trip along Moscow-river, lunch included
	17.00	Transfer to Olympiets
	19.00-21.00	Lab safety instructions in groups
July 18 Wednesday	8.00	Buses depart to the Practical Exam, MSU
	10.00-15.00	Practical Exam, MSU Chemistry Department
	17.00-18.30	Walk-around MSU Campus & Lenin Hills
	19.00-22.00	Circus show
July 19 Thursday	8.30-19.30	Whole-day excursion to Sergiev Posad
July 20 Friday	8.00	Buses depart to the Theoretical Exam, MSU
	10.00-15.00	Theoretical Exam, MSU Chemistry Department
	17.00-18.00	Walk to "Vorobjovi Gori" berth
	18.00-22.00	Re-union Party on a boat, dinner included
	22.00	Transfer to Olympiets
July 21 Saturday	8.40	Buses depart to excursions
	10.00-14.00	Excursion to Kremlin
	15.00-18.00	Excursion to Moscow Zoo
	18.00	Transfer to Olympiets
July 22 Sunday	9.00-13.00	Paintball & "Adventurer" game
	14.00-18.00	Free time, sports activities
	19.00-23.00	Disco
July 23 Monday	9.00-12.00	Free time
	12.40	Buses depart to the Closing Ceremony, MSU
	15.00-18.00	Closing Ceremony, MSU *Assembly Hall*
	18.00-18.30	Walk-around MSU Campus
	18.30	Buses depart to the Farewell Banquet
	19.00-23.00	Farewell Banquet, *Russian Academy of Sciences*
	23.00	Transfer to Olympiets
July 24 Tuesday	9.00-12.00	Check-out
	Whole day	Departures
	12.00	Late departures – staying in Olimpiets

Mentors and observers

July 15 Sunday	Whole day	Arrivals, Registration at Chemistry Department, MSU
		Transfer to Holiday Inn
	22.00-24.00	Get-together party, Holiday Inn, *Vorobjevy Gory Hall*
July 16 Monday	9.00	Buses depart to the Opening Ceremony, MSU
	11.00-13.00	Opening Ceremony, MSU *Intellectual Centre – Fundamental Library*
	13.00-15.00	Welcome Reception, MSU *Main Building*
	15.00-16.00	Lab inspection
	16.30	Buses depart to Holiday Inn, distribution of Practical Exam
	18.00-19.00	Consultation with tasks authors, *Polyanka Hall*
	20.00-24.00	The 1st Jury Meeting, *Sokolniki 2 Hall*
July 17 Tuesday	Whole day	Translation of Practical Exam, Holiday Inn, *Sokolniki Hall*
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 18 Wednesday	9.30-14.00	Excursions in groups: Kremlin/City tour
	17.30-19.00	Consultation with tasks authors, *Arbat Hall*
	20.00-24.00	The 2nd Jury Meeting, *Okhotnyi Ryad & Vorobjevy Gory Halls*
July 19 Thursday	Whole day	Translation of Theoretical Exam, Holiday Inn, *Sokolniki Hall*
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 20 Friday	8.00-18.00	Whole-day excursion to Sergiev Posad, lunch included
	18.00-22.00	Re-union Party on a boat, dinner included
	22.00	Transfer to Holiday Inn
July 21 Saturday	9.30-14.00	Excursions in groups: City tour/Kremlin
	15.00-19.00	Grading of students' works
	20.00-22.00	The 3rd (Business) Jury Meeting, *Sokolniki 1 Hall*
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 22 Sunday	8.00-19.00	Arbitration in groups, *Arbat Hall*
	20.00-21.00	Meeting with Minister of Education, RF and sponsors, *Sokolniki 1 Hall*
	21.00-22.00	The 4th Jury Meeting, Allocation of medals, *Sokolniki 1 Hall*
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 23 Monday	10.00-12.30	Free time, souvenir hunting
	13.30	Buses depart to the Closing Ceremony, MSU
	15.00-18.00	Closing Ceremony, MSU *Assembly Hall*
	18.00-18.30	Walk-around MSU Campus
	18.30	Buses depart to the Farewell Banquet
	19.00-23.00	Farewell Banquet, *Russian Academy of Sciences*
	23.00	Buses depart to Holiday Inn
	24.00-02.00	Informal Farewell Party, Holiday Inn, *Vorobjevy Gory Hall*
July 24 Tuesday	9.00-12.00	Check-out
	Whole day	Departures
	12.00	Late departures – transfer to Olimpiets hotel

Guests

July 15 Sunday	Whole day	Arrivals, Registration at Chemistry Department, MSU
		Transfer to Holiday Inn
	22.00-24.00	Get-together party, Holiday Inn, *Vorobjevy Gory Hall*
July 16 Monday	9.00	Bus departs to the Opening Ceremony, MSU
	11.00-13.00	Opening Ceremony, MSU *Intellectual Centre – Fundamental Library*
	13.00-15.00	Welcome Reception, MSU *Main Building*
	15.00-18.00	Moscow City tour
July 17 Tuesday	10.00-14.00	Excursion to Kremlin, the Diamond Hall
	15.00-19.00	Free time, souvenir hunting
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 18 Wednesday	10.00-13.00	Excursions to the Tret'yakov gallery
	13.00-15.00	Lunch, "Godunov" restaurant, center of Moscow
	15.00	Transfer back to the Holiday Inn.
July 19 Thursday	9.00-14.00	Excursion to the Kolomenskoe park
	17.30	Bus departs to the Moscow Circus, Tsvetnoi blvd.
	19.00-22.00	Circus show
	23.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 20 Friday	8.00-18.00	Whole-day excursion to Sergiev Posad
	18.00-22.00	Re-union Party on a boat
	22.00	Transfer to Holiday Inn
July 21 Saturday	10.00-14.00	Walk in the center of Moscow, Arbat
	15.00-19.00	Free time
	22.00-24.00	Informal party, Holiday Inn, *Vorobjevy Gory Hall*
July 22 Sunday	9.00-13.00	Excursion to the Cathedral of Christ the Savior
	15.00-19.00	Excursion to the Izmailovo exhibition
	20.00-21.00	Meeting with the Minister of Education, RF and sponsors, *Sokolniki 1 Hall*
July 23 Monday	9.00-12.30	Free time, souvenir hunting
	13.30	Buses depart to the Closing Ceremony, MSU
	15.00-18.00	Closing Ceremony, MSU *Assembly Hall*
	18.00-18.30	Walk-around MSU Campus
	18.30	Buses depart to the Farewell Banquet
	19.00-23.00	Farewell Banquet, *Russian Academy of Sciences*
	23.00	Buses depart to Holiday Inn
	24.00-02.00	Informal Farewell Party, Holiday Inn, *Vorobjevy Gory Hall*
July 24 Tuesday	9.00-12.00	Check-out
	Whole day	Departures
	12.00	Late departures – transfer to Olimpiets hotel

Minutes of the Business Sessions of the 39th IChO in Moscow

MINUTES of the BUSINESS PART of the
1st JURY SESSION at the 39th ICHO/MOSCOW
July 16th, 2007 (20.30 – 21.50)
Chair of the BUSINESS PART: Manfred Kerschbaumer

1. Presentation of the agenda for the meeting.
2. Number of delegations present at 20.30: 60
3. Short report of the ISC Meeting in December 2006:

   Detailed minutes of the ISC-meeting may be found in the appendix of the Preparatory Problems for Moscow 2007;

   ISC is aware of the situation with level 3 tasks – work on that has already begun.

   In the business session of IChO (Jury session #3) Andras Kotschy (Hungary) will distribute a proposal by Gabor Magyarfalvi (Hungary) for a new syllabus.
4. Change of regulations: possibility of a 2nd Scientific Observer

   Regulations § 3, 1:

   *Each participating country's delegation may consist of four competitors and two accompanying persons (also known as mentors). Countries may include **one** scientific observer in their delegation.*

   Proposal:

   *Each participating country's delegation may consist of four competitors and two accompanying persons (also known as mentors). Countries may include **two** scientific observer in their delegation.*

   Comments: Anton **Sirota** (Slovakia): strongly against it, regulations should not be changed within such a short period, problems with financing, no necessity for a 2nd scientific observer if task are shorter;

   I-Jy **Chang** (Taiwan): 2nd scientific observer extremely important for Asian countries due to time consuming translation work;

   Carlos **Castro-Acuna** (Mexico): 2nd scientific observer decreases injustice in connection with language groups;

   Marek **Orlik** (Poland): against it, because too many people in the Jury sessions;

Azerbaijan: supports proposal, because in case of changing the mentors (“generation change”) 2[nd] scientific observer may learn a lot;

Voting: A qualified majority would be 45 votes out from possible 66 (countries)

Result: **50 votes supporting the proposal ⇒ CHANGE ACCEPTED**

5. Change of regulations: another definition of Honorable Mentions

Regulations § 15, 5:

An honorable mention is awarded to competitors who do not receive a medal, but gain full marks for at least one problem.

Proposal:

An honorable mention is awarded to competitors who ***are among the best 10% of non medalists****.*

Comments: Carlos **Castro-Acuna** (Mexico): his proposal, more justice for students who miss the bronze medals very tightly

Several other comments in favour of the change.

Voting: A qualified majority would be 45 votes out from possible 66 (countries)

Result: **47 votes supporting the proposal ⇒ CHANGE ACCEPTED**

6. Agenda for the Business Session of the IChO (draft)
   - Information by the Minister of Education and Science of Russia
   - Election of new SC-members: one from Europe, two from Pacific Rim (proposals!)
   - Distribution of “Gabor’s” proposal concerning new syllabus and comments on it
   - IUPAC-support
   - Future Olympiads (presentation from Hungary)
   - Any other business

MINUTES of the BUSINESS SESSION of the 39th ICHO/MOSCOW

July 21st, 2007 (20.15 – 22.15)

Chair of the BUSINESS SESSION: Manfred Kerschbaumer

63 delegations are present.

Dr. Kerschbaumer presents the agenda of the meeting:

- **Election of new SC-members:**
  one from Europe, one from Asia, one from Pacific Rim
- **Level and length of competition – new syllabus:**
  Information about "Gabor's" proposal
- **Level and length of competition – proposal to cut down the number of characters**
- **IUPAC-support**
- **Future Olympiads**
- **Information about arbitration**

- ***Election of new SC-members:***

The following proposals are presented to the International Jury:

EUROPE:	Wesley Brown (Ireland)
	Kurt Nielsen (Denmark)
ASIA:	Duckwhan Lee (Korea)
PACIFIC RIM:	Mark Ellison (Australia)

As **Duckwhan Lee** and **Mark Ellison** are the only candidates from their respective regions, no election is necessary, they will be members of the SC for the next two years.

After short self presentations from the two European candidates, the jury elects **Wesley Browne** with 36 votes (**Kurt Nielsen**: 19 votes) as the third member of the SC from Europe.

Dr. Kerschbaumer thanks the parting member of SC, **I-Yi Chang** from Taiwan, **Geoff Salem** from Australia, and **Paraic James** from Ireland.

The members of the current SC are listed in appendix A.

- ***Level and length of competition – new syllabus:***

Manfred Kerschbaumer reports from the SC-meeting in December 2006 where the SC stated that in all the years before the regulation concerning the allowed number of level 3 topics was violated. So it was the duty of the SC to try and change this abuse.

Andras Kotschy from Hungary presents the proposal by Gabor Magyarfalvi which changes the old syllabus in its basics. Instead of topics belonging to three different levels, the new syllabus contains a section “concepts and skills” and a section “factual knowledge”.

In both sections there is a list of concepts and skills or factual knowledge respectively which can be expected from the participants to be familiar with, and a list which must be covered in the preparatory problems.

A hard copy with the details of this proposal is distributed. The members of the International Jury are requested to give comments.

- ***Level and length of competition - proposal to cut down the number of characters***

Manfred Kerschbaumer proposes to cut down the number of characters allowed in the theoretical and practical competition (25.000 each, § 13, 4 of the regulations) to 22.000. He also points out that a lower number of characters does not imply an easier set of tasks because a guiding explanation needing more words may be simpler for a student than a short task with even shorter questions.

The head mentor from Belgium (Sebastien Delfosse) proposes to decrease this number to 20.000 characters.

The jury decides to vote about both proposals with 38 votes in favour.

As a change of the allowed number of characters means a change in the regulations, a qualified majority (45 votes) is necessary. After some discussion voting was carried out:

In favour to cut down to 20.000 characters: 27 votes

In favour to cut down to 22.000 characters: 35 votes

As this is not a qualified majority the current regulation (25.000) will not be changed.

- ***IUPAC-support***

Manfred Kerschbaumer reports about an offer from the president of IUPAC (Bryan O. Henry) in Korea to support the ICHO in some way. From December 2006 till June

2007, Dr. Kerschbaumer managed to negotiate an annual donation of US $ 10.000 to help countries with financial troubles. A “Memorandum of Understanding” was established (appendix B) which shows the details of a possible support for the countries mentioned above.

- **Future Olympiads (presentation from Hungary)**

Andras Kotschy shows a detailed presentation about the 40th ICHO in Budapest. It will be held at the Eötvös Loránd University from July 12th to July 21st. Andras distributes the issue No. 1 of the Catalyzer.
Yoshiyuki Sugahara presents some details about the 42nd ICHO in Tokio in 2010.
The then following host will be Turkey (2011) and USA (2012). John Kotz (USA) informs about the possible venue of the 44th ICHO: Boston or Chicago.

- **Information about arbitration**

Sasha Gladilin refers about the procedure of arbitration the next day. This time the sequence is not alphabetically but is decided by drawing lots.

APPENDIX A:

STEERING COMMITTEE OF THE ICHO

as constituted on July 22, 2007

Elected members:

Representatives of Europe:

Manfred Kerschbaumer (Austria), ***chairman***; e-mail: mkersch@gmx.net

Alexander K. Gladilin (Russia); e-mail: gladilin@direct.ru

Wesley Browne(Ireland); e-mail: w.r.browne@rug.nl

Representative of the Americas

Carlos Castro-Acuna (Mexico); e-mail: castroacuna02@yahoo.com

Representatives of Asia and the Pacific Rim:

Marc Ellison (Australia); e-mail: u3903111@anu.edu.au

Duckwhan Lee (Korea); e-mail: duckhwan@sogang.ac.kr

Non-elected members:

Representatives of the organizers:

Valerie Lunin (Russia); e-mail: vvlunin@kge.msu.ru

Andras Kotschy (Hungary); e-mail: kotschy@chem.elte.hu

Peter Wothers (United Kingdom); e-mail: pdw12@cam.ac.uk

Representative from Japan

Experts:

Wolfgang Hampe (Germany); e-mail: hampe@t-online.de

Gabor Magyarfalvi (Hungary); e-mail: gmagyarf@chem.elte.hu

Kurt Nielsen (Denmark); e-mail: Kurt_B_Nielsen@post.tele.dk

Anton Sirota (Slovakia); e-mail: anton.sirota@stuba.sk

APPENDIX B:

Memorandum of Understanding

(IUPAC-support for the IChO)

- IUPAC will support the International Chemistry Olympiad by an annual donation of US$ 10 000. This grant can be terminated by IUPAC after giving notice 12 months in advance of the next IChO.
- The president of IUPAC (or nominee) will be invited to the closing
- ceremony of the IChO to give a short (5 to 10 minutes) address and to take part in the gold medal presentations.
- The first financial support will be for the 40th IChO in Budapest (Hungary) 2008.
- The money will be transferred to an account of the annual host (2008: Hungary).
- Countries who wish to apply for support will make a written application (non-formal) to the chair of the Steering Committee (SC) of the IChO. The application must contain the amount of money needed, and a (detailed) description of the problems of raising money for the IChO in that particular country. Deadline for the application is November 30th.
- The chair of the Steering Committee will present all applications to the SC in its annual meeting at the beginning of December the year preceding the IChO in question.
- The SC will make decisions regarding the distribution of the money considering the following items: The money will be distributed to
  - countries which cannot afford the participation fee and therefore cannot participate in the IChO
  - countries which can not travel with a team of four students,
  - countries which can not travel with two mentors.
- If the US$ 10 000 support is not fully allocated for a particular IChO, the unused part of the donation will be transferred to the next host.
- The IChO will provide IUPAC with a summary report of the distributions made from the IUPAC grant.

Bryan R. Henry (Date)	Manfred Kerschbaumer (Date)
President IUPAC	Chairman of the Steering Committee
	of the International Chemistry Olympiad

PRACTICAL EXAMINATION PROBLEMS

General Directions

- **safety rules:** follow them as in the Preparatory problems described, no eating or drinking is allowed in the lab.
- **violating safety rules:** you get one warning, offend again: you are out.
- **problem booklet:** 12 pages (incl. cover sheet and Periodic table of elements) with 2 problems. Start with problem 1.
- **time:** 5 hours; 30 minutes warning before the end.
- **answer sheets: 5** pages (incl. cover sheet).
- **your name and student code:** write it on **every** answer sheet.
- **answers:** only in the appropriate places of the answer sheets, nothing else will be marked. Relevant calculations have to be shown.
- **use only the pen and calculator provided.**
- **results:** the number of significant figures in numerical answers must conform to the rules of evaluation of experimental error. Mistakes will result in penalty points even if your experimental technique is flawless.
- **burette:** read it as accurately as possible.
- **more chemicals** needed? Ask your lab assistant. No penalty for this.
- **Extra sample to be analyzed or broken column:** a penalty of 10 marks.
- **questions** concerning safety, apparatus, chemicals, organization, toilet break: **ask your lab assistant.**
- **chemical waste:** put it only in the designated containers.
- **official English-language version available** on request **for clarification only.** Ask your lab assistant.
- **after the stop signal** put your answer sheets and spectra in the envelope (don't seal), deliver them to your lab assistant. Keep the problem booklet together with the pen and calculator.
- **You must stop your work immediately after the stop signal has been given. A delay of 5 minutes will result in zero points for the current task.**
- **During the Practical examination some of your glassware and plastics may have to be used more than once. Clean it carefully.**

List of Chemicals

Reagent	Quantity	Placed in	Labeled
	Task 1		
Eluent 1	100 mL	Amber glass bottle*	Eluent 1
Eluent 1	1 mL	Plastic microtube	Eluent 1
Eluent 2	50 mL	Amber glass bottle*	Eluent 2
Eluent 2	1 mL	Plastic microtube	Eluent 2
Eluent 3	50 mL	Amber glass bottle*	Eluent 3
Eluent 3	1 mL	Plastic microtube	Eluent 3
0.5 M Carbonate buffer solution, pH 9.5	10 mL	Glass vial	$NaHCO_3$
0.5 M Tris-HCl buffer solution, pH 8.5	10 mL	Glass vial	Tris-HCl
Mixture of amino acids to be analyzed**	1.2 mL	Plastic microtube	A number between 301 and 600
Ellmann reagent: 0.2 M Phosphate buffer solution containing 10 mM EDTA and 3 mM 5,5'-Dithiobis(2-nitrobenzoic acid), pH 7.0	10 mL	Glass vial	DTNB
Pauli's reagent: solution of sodium 4-diazonium-benzenesulfonate in 0.1 M aqueous HCl	1 ml	Plastic microtube	Pauli
Sodium hydroxide, 10% aqueous solution	10 mL	Glass vial	NaOH 10%
8-Hydroxyquinoline, 5.2 mM solution in ethanol/n-butanol (9:1) mixture	5 ml	Glass vial	8-HQ
Sodium hypobromite, 0.24 M solution in 10% aqueous NaOH	1.2 ml	Plastic microtube	NaBrO
2,4,6–Trinitrobenzenesulfonic acid, 3.4 mM aqueous solution	1 mL	Plastic microtube	TNBS
8 M Aqueous urea solution	1 mL	Plastic microtube	Urea
	Task 2		
HCl, standard solution, ~1 M (see exact value on the label)	40 mL	Amber glass vial	HCl <and exact concentration>
NaOH (to be standardized)	200 mL	Amber glass vial	NaOH
Powdery sample to be analyzed**	0.5 – 1 g	150 mL beaker covered with watch glass	<number of workplace>
H_2O distilled	400 mL	Plastic wash bottle	H_2O
H_2O distilled (shared between 2 students)	30 mL	Glass drop bottle	H_2O
H_2O distilled (for common use)	5 L	Bottle with tubing and clamp on top of the bench	H_2O
NaH_2PO_4, 15% solution (shared between 2 students)	20 mL	Glass drop bottle	NaH_2PO_4 15%
Bromocresol Green, 0.5% solution in 20% ethanol (shared among 3-4 students in a raw)	30 mL	Glass drop bottle	Bromcresol green
Thymolphthalein, 0.5% solution in ethanol (shared among 3-4 students in a raw)	30 mL	Glass drop bottle	Thymolphtalein
$K_2C_2O_4$, 15% solution (shared between 2 students)	50 mL	Amber glass vial	$K_2C_2O_4$ 15%

*Fixed on the top shelf (do not try to remove), with connected tubing and clamp
**10 marks penalty for an extra portion of the sample

Components of Eluents 1 to 3

Eluent 1: 0.1 M aqueous sodium citrate, 50 mM sodium chloride, 40 mM thiodiglycol, 1 mM caprylic acid, 0.1% Brij-35; pH 4.9.
Eluent 2: 0.2 M aqueous sodium phosphate, 0.1% Brij-35; pH 7.0.
Eluent 3: 0.2 M aqueous sodium hydroxide.

Apparatus and Suppliers

Item	Quantity
Test tube rack	1
Laboratory stand	1
Chromatography column with ion-exchange resin	1
Laboratory stand with white covering	1
Double clamp for burette	1
Ring for funnel	1
25 mL Burette	1
100 mL flask labeled "Waste"	1
100 mL Volumetric flask	2
100 mL Erlenmeyer flask	2
Syringe with needle	1
Graduated test tubes for collecting fractions and preparing mixtures	50
96-well plate	1
Pipettor (micropipette) with fixed volume of 0.1 mL	1
Disposable tips (in blue plastic cup)	20
Spectrophotometric cuvettes labeled "A1", "B1", "A2", "B2", "A3", "B3" in cuvette holder	6
10 mL Graduated plastic pipettes	3
10 mL Glass pipette	1
Pipette filler	1
3-Way Bulb	1
Glass rod	1
Filter funnel	1
Small funnel	1
60 mL Amber glass vials for combined fractions (peaks)	3
10 mL Measuring cylinder labeled "$K_2C_2O_4$ 15%" (shared between 2 students)	1
10 mL Measuring cylinder (shared between 2 students)	1
50 mL Measuring cylinder	1
100 mL Measuring cylinder labeled "H_2O" (shared among 3-4 students in a row)	1
Plastic plate with filters*** (shared among 3-4 students in a row)	3 filters per student
Heating plate (for common use in a fume hood)	6 plates per hood
Rubber protection tips (for common use a fume hood)	6 pairs per hood
Spectrophotometer (shared by a group of students; see the number of the spectrophotometer to be used at your bench "SP____")	
Marker	1
Ruler	1
White sheet of paper	1

***If needed, ask your lab assistant for extra filters.

Safety regulations, S-phrases, R-phrases

Disodium hydrogen phosphate	R:36/37/38 S:26-36
Ethylenediaminetetraacetic acid, disodium salt	R:36/37/38 S:26-36/37/39
Tris-HCl	R:36/37/38 S:26-36
Arginine	R:36 S:26
Cysteine	R:22
Histidine	S:22-24/25
Hydrochloric acid	R:34-37 S:26-36-45
Sodium 4-diazoniumbenzenesulfonate	R:1-37/37 S:26-36
Sodium hydroxide	R:34-35 S:26-36-37/39-45
8-Hydroxyquinoline	R:22-36/37/38 S:26-36/37
Ethanol	R:11 S:7-16
Butanol-1	R:10-22-37/38-41-67 S:7/9-13-26-37/39-46
Sodium hypobromite	R31-34 S:26-36-45
5,5'-Dithiobis(2-nitrobenzoic acid)	R:36/37/38 S:26-36
2,4,6-Trinitrobenzene sulfonic acid	R: 1-22-36/38-43 S: 26-36/37
Sodium chloride	R:36 S:26
Thiodiglycol	R:36 S:26
Caprylic acid	R:34 S:26-27-45-36/37/39
Brij-35	R:36/37/38 S:26-36
Sodium dihydrogen phosphate	S:22-24/25
Sodium carbonate	R:36 S:22-26
Calcium carbonate	R:41-37/38 S:26-39
Bromocresol Green	S:22-24/25
Thymolphthalein	S:22-24/25
Potassium oxalate	R:34 S:26-27-36/37/39

Risk Phrases

Indication of Particular Risks

R1: **Explosive when dry**
10: **Flammable**
22: **Harmful if swallowed**
31: **Contact with acids liberates toxic gas**
34: **Causes burns**
35: **Causes severe burns**
36: **Irritating to the eyes**
37: **Irritating to the respiratory system**
41: **Risk of serious damage to eyes**
43: **May cause sensitization by skin contact**
67: **Vapors may cause drowsiness and dizziness**

Combination of Particular Risks

R24/25: **Toxic in contact with skin and if swallowed**
36/37/38: **Irritating to eyes, respiratory system and skin**
36/38: **Irritating to eyes and skin**
37/38: **Irritating to respiratory system and skin**

Safety Phrases

Indication of Safety Precautions

S13: Keep away from food, drink and animal feeding stuffs
22: **Do not breathe dust**
26: **In case of contact with eyes, rinse immediately with plenty of water and seek medical advice**
27: **Take off immediately all contaminated clothing**
36: **Wear suitable protective clothing**
39: **Wear eye/face protection**
45: **In case of accident or if you feel unwell, seek medical advice immediately (show label where possible)**
46: **If swallowed, seek medical advice immediately and show this container or label**

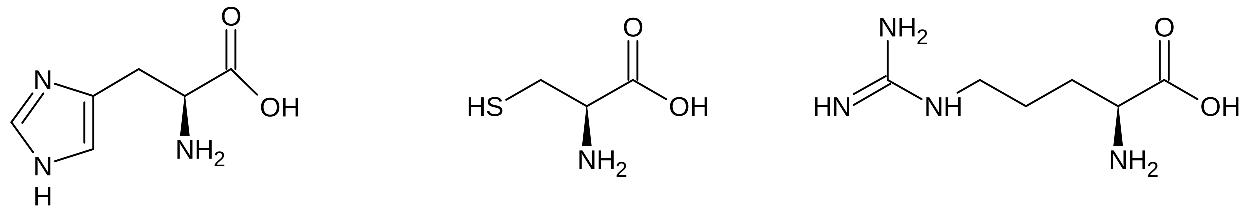
Combination of Safety Precautions

7/9: **Keep container tightly closed and in a well-ventilated place**
24/25: **Avoid contact with skin and eyes**
36/37/39: **Wear suitable protective clothing, gloves and eye/face protection**
37/39: **Wear suitable gloves and eye/face protection**

Problem 1. ION-EXCHANGE CHROMATOGRAPHY OF AMINO ACIDS

20 points

Ion-exchange chromatography is an important analytical and preparative method, which allows fractioning of charged substances. Interaction of ionic groups of the substances with counterions attached to the resin is behind the method. In this task you will have to carry out separation of a given mixture of three amino acids followed by quantitative assay of individual amino acids eluted from the column by using specific chromogenic reactions. Since queues of students are possible at spectrophotometers, we **strongly suggest you starting the exam with Problem 1**.



His Cys Arg

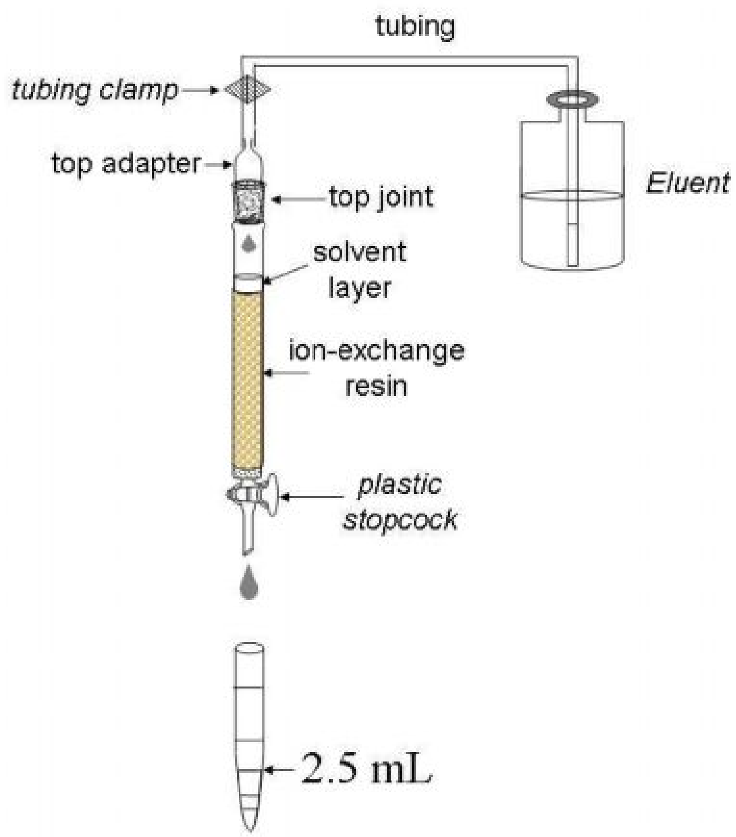
Three amino acids (see the structures above) are present in the mixture. These are histidine, cysteine, and arginine. Cross-linked sulfonated polystyrene is used as a cation-exchange resin (see the picture of the system below). At the beginning of the experiment the column is equilibrated with Eluent 1 (pH 4.9).

Procedure

Chromatography. Step 1

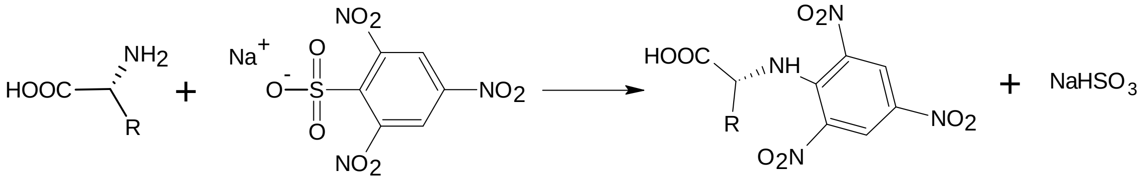
Apply the given solution of a mixture of amino acids to the column. First, open the stopcock to allow the solvent in the column draining into the Erlenmeyer flask labeled "Waste" so that the solvent is level with the top of packing material, still preventing the resin surface from drying off. Close the stopcock and carefully add the analyzed solution to the top of the column by using a syringe. Open the stopcock and let the sample soak inside the gel (drain the solvent into the "Waste" flask). Close the stopcock and add about 1 mL of Eluent 1 (corresponds to ~ 1 cm of liquid in the column) by carefully releasing the tubing clamp. Attach the top joint tightly, fixing the column with one hand and the adaptor with the other (be sure that the joint is fitted closely to the column). Replace the "Waste" flask at the stand with the test tubes in the rack. Release the tubing clamp and open the stopcock to let the eluent flow down through the column. Proceed with elution. (Always open the stopcock to start elution and close the stopcock to stop it).

Collect the fractions in the test tubes up to the volume of 2.5 mL (as shown in the Picture). If needed, label them with marker. After collecting each 4 to 8 fractions stop elution and carry out qualitative analysis of the collected samples.



Qualitative analysis of samples

Qualitative assay of amino acids is based on the reaction of their α-amino groups with sodium 2,4,6–trinitrobenzene sulfonate (TNBS):



The assay is carried out in the wells of a polystyrene plate, each well corresponding to a definite test tube. Before starting the assay, mix 1 mL of TNBS solution with 10 mL of carbonate buffer solution and place 0.1 mL of the resulting mixture into half of the plate wells (from A1 to H5). Then add 0.1 mL of the analyzed fraction into a well. Start with A1 well and continue with B1, C1, etc (move top to bottom and left to right). If an amino acid is present in the analyzed fraction, intense yellow coloration will develop in the corresponding well within 3 min. Use the coloration in the first well as the reference. To reliably estimate the coloration, place the plate on the white sheet of paper.

Note: all aliquots of 0.1 mL should be added by using the pipettor. We expect you to use one tip for all fractions of a single peak.

1.1a *Draw the profile of coloration intensity (qualitatively) on the plate sketch in the Answer Sheet. Use the following symbols: (–) – no coloration, 1 – weak coloration, 2 – moderate coloration and 3 – intense coloration. Keep drawing the profile during the whole chromatography process.*

Continue collecting fractions and analyzing them until you get **at least two wells with coloration as in A1 well**, which will indicate that the first amino acid has left the column completely (end of the first peak).

Chromatography. Step 2

As soon as you are finished with collecting the first peak, change to Eluent 2. To do so, close the stopcock, fix the tubing clamp (**Important!**), disconnect the tubing leading to the bottle with Eluent 1 and connect the tubing leading to the bottle with Eluent 2. Attach the top joint tightly.

1.1b *Indicate when the eluents have been changed by drawing lines between the corresponding wells on the plate sketch.*

Continue elution, collecting fractions and carrying out qualitative analysis of samples as described above.

Chromatography. Step 3

As soon as you are finished with collecting the second peak, change to Eluent 3 as described in Step 2. Continue chromatography until the third amino acid leaves the column completely.

Stop chromatography by closing the stopcock and fixing the clamp.

Based on the results of qualitative analysis, choose the fractions which contain the amino acids.

1.1c *Write down in the Answer Sheet the labels of wells corresponding to the chosen fractions.*

1.2 *Combine the fractions from each peak and measure the volumes of combined fractions using a measuring cylinder. Report the volumes of combined fractions excluding amounts used for the qualitative analysis. Write down the obtained results in the Answer Sheet.*

Pour combined fractions in the amber glass vials labeled “Peak 1”, “Peak 2”, “Peak 3”. Prepare samples for quantitative spectrophotometric analysis as described below.

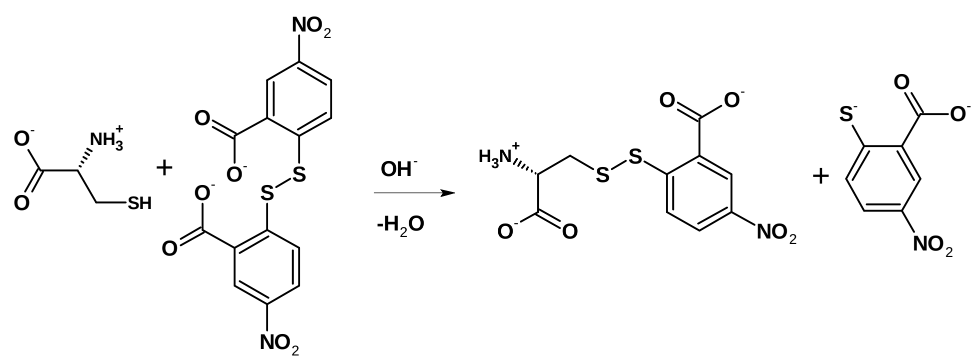
When finished with Practical exam, close the vials and leave them on the table. The combined fractions will be subsequently analyzed by lab staff.

<u>**Spectrophotometric analysis**</u>

For each probe, you should submit two cuvettes to the operator. Prepare the probes as follows.

Important! When storing, always put cuvettes in the cuvette holder! All cuvettes have 2 ribbed and 2 working vertical surfaces. While operating with cuvettes, do not touch working surfaces, otherwise you may get incorrect values of absorbance.

Assay 1 (peak 1). Cysteine concentration is determined by the Ellmann reaction:



Test tube A1 (Reference). Place 0.1 mL of Eluent 1 from plastic microtube into a test tube and add 2.9 mL of Ellmann reagent (DTNB).
Test tube B1 (Sample). Place 0.1 mL of the analyzed solution into a test tube and add 2.9 mL of Ellmann reagent (DTNB).
Mix the contents of the test tubes thoroughly and transfer each mixture to the corresponding cuvettes labeled A1 (for reference) and B1 (for sample).

Assay 2 (peak 2). Determination of histidine concentration is based on the ability of imidazole moiety to react with diazonium compounds (Pauli reaction).

Test tube A2 (Reference). Place 2.8 mL of Tris-HCl buffer solution into a test tube, add 0.1 mL of Eluent 2 from plastic microtube and 0.1 mL of Pauli reagent.
Test tube B2 (Sample). Place 2.8 mL of Tris-HCl buffer solution into a test tube, add 0.1 mL of the analyzed solution and 0.1 mL of Pauli reagent.

Mix the contents of the test tubes thoroughly and transfer each mixture to the corresponding cuvettes labeled A2 (for reference) and B2 (for sample).

Assay 3 (peak 3). Determination of arginine concentration is based on the ability of guanidinium moiety to react with some phenols under alkaline and oxidative conditions (Sakaguchi reaction).

Test tube A3 (Reference). Place 0.1 mL of Eluent 3 into a test tube and add 1.5 mL of 10% NaOH solution, 1 mL of 8-hydroxyquinoline solution and 0.5 mL of sodium hypobromite solution.
Test tube B3 (Sample). Place 0.1 mL of the analyzed solution into a test tube and add 1.5 mL of 10% NaOH solution, 1 mL 8-hydroxyquinoline solution and 0.5 mL of sodium hypobromite solution.

Shake the test tubes vigorously for 2 min (**Important!**) and observe formation of orange color. Add 0.2 mL of 8 M urea solution to each test tube, mix the contents and transfer about 3 mL of each mixture to the corresponding cuvettes labeled A3 (for reference) and B3 (for sample).

All mixtures should be analyzed by spectrophotometry not earlier than 10 min and not later than 2 h after preparation. Submit the set of 6 cuvettes to the spectrophotometer operator. In case of a queue at the spectrophotometer, ask the operator to put your student code on the list at the signboard. You will be invited by the operator in due time. Meanwhile, you can answer the theoretical question and start fulfilling Problem No 2.

In case your sample(s) have not been subjected to studies within the proper time interval (which is quite improbable), prepare the sample(s) afresh.

Get the print-offs with the spectra of your samples and check it. Sign the print-offs and get the operator's signature.

1.3 *Determine absorbance at the corresponding wavelengths and calculate the content (in mg) of each amino acid in the mixture you were given. The optical length is 1.0 cm. Complete the Answer Sheets taking into account that one mole of each amino acid gives one mole of the corresponding product.*

Reference data:

The values of extinction coefficients: Product of Ellmann reaction: 13600 $M^{-1}cm^{-1}$ at 410 nm Product of Pauli reaction: 6400 $M^{-1}cm^{-1}$ at 470 nm Product of Sakaguchi reaction: 7700 $M^{-1}cm^{-1}$ at 500 nm	Molar masses of the amino acids. Cysteine 121 g/mol Histidine 155 g/mol Arginine 174 g/mol

1.4. *Draw three resonance structures of the species responsible for mixture coloration as a result of Ellmann reaction.*

Problem 2. DETERMINATION OF CARBONATE AND HYDROGEN PHOSPHATE IN AN ABRASIVE SAMPLE

20 points

Na_2CO_3, $CaCO_3$ and Na_2HPO_4 are the main constituents of abrasive powders. In this task you will have to determine carbonate and hydrogen phosphate ions in an abrasive sample by two acid-base titrations.

First, the exactly known amount of hydrochloric acid (taken in an excess) is added to the sample. As a result, hydrogen phosphates are transformed into H_3PO_4, whereas carbonates into CO_2 which is further removed by boiling. Calcium ions initially present in the sample pass into the solution. Because of possible interference in subsequent analysis, they are precipitated as CaC_2O_4 and filtered off prior to the titration.

Next, the phosphoric acid formed is subjected to two titrations with pre-standardized NaOH solution and two different indicators: Bromocresol Green (BCG) and Thymolphthalein (TP). First, H_3PO_4 (and excess of HCl) is titrated to $H_2PO_4^-$ ion, the endpoint lying in slightly acidic medium (pH of ~4.5). It corresponds to the color change of BCG from yellow to blue. The second titration proceeds till HPO_4^{2-} is formed. The endpoint of the second titration corresponds to the color change of TP from colorless to blue (moderately alkaline medium, pH of ~10).

The content of CO_3^{2-} ions in the sample is calculated by finding the difference between:

a) the amount of the titrant equivalent to the initial amount of HCl (taken for the sample dissolution) and
b) the amount of the titrant corresponding to the second endpoint (TP).

The content of HPO_4^{2-} is calculated by finding the difference between the amounts of the titrant consumed to achieve two endpoints (TP and BCG).

Procedure

Step 1. Dissolution of the sample and removal of CO_2

To the sample of the abrasive powder in a beaker covered with watch glass add 10.00 mL (**exactly, with a pipette! *Carefully*, not removing the glass and avoiding losses because of splashing!**) of ca. 1 mol/L HCl (see the exact concentration of the acid on the label). After the most intensive stage of gas evolution is completed, heat ***carefully*** the solution in the beaker (covered with watch glass) on a heating plate until the gas evolution stops. Then bring the solution to boiling and boil it carefully for 2-3 min.

Step 2. Precipitation of calcium

Remove the beaker from the plate; wash the steam condensate from the watch glass down to the beaker with distilled water. Add 1-2 mL of 15% $K_2C_2O_4$ solution with measuring cylinder. Put the beaker aside until the most part of the precipitate is formed (usually takes 10 to 20 min). Spend this time for standardization of the titrant solution of NaOH (see the procedure hereunder).

Step 3. Standardization of NaOH solution

Place with a pipette 10.00 mL of HCl solution into a 100 mL volumetric flask, make up to the mark with distilled water and mix. Fill the burette with NaOH solution. Transfer with a pipette 10.00 mL of the diluted HCl solution from the volumetric flask to an Erlenmeyer flask. Add 1-2 drops of Thymolphthalein solution and titrate with NaOH solution until blue coloration stable on swirling for 5-10 s appears.

Here and after. Repeat the titrations as necessary. It is desirable that the highest and the lowest titrant volume values differ not more than by 0.10 mL. Report all the final volume values with 0.01 mL accuracy.

2.1a *Complete the table in the Answer Sheet.*
2.1b *Calculate the concentration of NaOH solution (in mol/L).*

Step 4. Filtering off calcium oxalate

After the most part of CaC_2O_4 precipitates filter the precipitate off collecting the filtrate into a 100 mL volumetric flask. Slight turbidity in the filtrate is admissible, since small amounts of calcium oxalate do not interfere in the titration. Wash the filter with distilled water; make up the solution in the flask to the mark with distilled water and mix. Put the used filter into the waste basket.

Step 5. Sample titration against Bromocresol Green

Transfer with a pipette a 10.00 mL aliquot of the sample solution coming from the step 4 from the volumetric flask to an Erlenmeyer one, and add 3 drops of BCG solution. Prepare in another Erlenmeyer flask a reference solution by adding 3 drops of 15 % NaH_2PO_4 solution and 3 drops of BCG solution to 15-20 mL of distilled water. Titrate the sample solution with NaOH solution until the color coincides with that of the reference solution.

2.2 *Complete the table in the Answer Sheet.*

Step 6. <u>Sample titration against thymolphthalein</u>

Transfer with a pipette a 10.00 mL aliquot of the sample solution coming from the step 4 from the volumetric flask to an Erlenmeyer one. Add 2 drops of TP solution and titrate with NaOH solution until blue coloration stable on mixing for 5-10 s appears.

2.3 *Complete the table in the Answer Sheet.*

Step 7. <u>Calculations</u>

2.4 Calculate the mass of CO_3^{2-} in the sample.

2.5 Calculate the mass of HPO_4^{2-} in the sample.

Step 8. <u>Additional questions to the problem</u>

Answer the additional questions in the Answer Sheets.

2.6a Indicate one reaction (write down the equation) for a process interfering in the sample analysis you have carried out in the presence of Ca^{2+}.

2.6b A list of mistakes possible at different steps is given in the table in the answer sheet. Indicate which of the mistakes can lead to errors in CO_3^{2-} and/or HPO_4^{2-} content determination. Use the following symbols: “0” if no error is expected, “+”or “–“ if the result is higher (positive error) or lower (negative error) than the true one.

THEORETICAL EXAMINATION PROBLEMS

General Directions

- Write your name and code number on each page of the answer sheet.
- You have 5 hours to fulfil the task. Failure to stop after the STOP command may result in zero points for the task.
- Write answers and calculations within the designated box.
- Use only the pen and the calculator provided.
- There are **18** pages of Problems (incl. Cover Sheet and Periodic Table) and **22** pages of Answer Sheet.
- An English-language version is available.
- You may go to the restroom with permission.
- After finishing the examination, place all sheets including Problems and Answer Sheet in the envelope and seal.
- Remain seated until instructed to leave the room.

Constants and useful formulas

Gas constant	$R = 8.314\ \text{J·K}^{-1}\text{·mol}^{-1}$
Avogadro constant	$N_A = 6.022 \cdot 10^{23}\ \text{mol}^{-1}$
Planck constants	$h = 6.626 \cdot 10^{-34}\ \text{J·s}$
	$\hbar = 1.055 \cdot 10^{-34}\ \text{J·s}$
Speed of light	$c = 3.00 \cdot 10^{8}\ \text{m·s}^{-1}$

Uncertainty relation	$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$
Gibbs energy of a condensed phase at pressure *p*	$G = pV + \text{const}$
Excess pressure caused by surface tension	$\Delta P_{in} = 2\sigma / r$
Relation between equilibrium constant and Gibbs energy	$RT \ln K = -\Delta_r G^\circ$
Isotherm of a chemical reaction	$\Delta G = \Delta G^\circ + RT \cdot \ln Q$ with $Q = \frac{\text{product of } c(\text{products})}{\text{product of } c(\text{reactants})}$
Arrhenius equation	$k = A \exp\left(-\frac{E_A}{RT}\right)$

$V(\text{cylinder}) = \pi r^2 h$

$S(\text{sphere}) = 4\pi r^2$

$V(\text{sphere}) = \frac{4}{3}\pi r^3$

Problem 1. PROTON TUNNELING

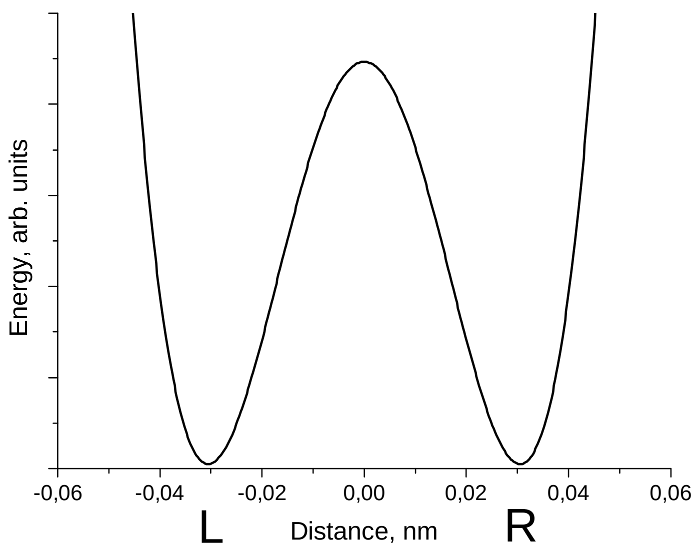
7 points

Proton tunneling through energy barriers is an important effect, which can be observed in many complex species containing hydrogen bonds (DNA, proteins, etc.). Propanedial (malonaldehyde) is one of the simplest molecules for which intramolecular proton transfer can occur.

1.1.1 *Draw the condensed formula of propanedial and the structures of two of its isomers, which can exist in equilibrium with propanedial.*

1.1.2 *In a water solution propanedial is a weak acid, its strength being comparable with that of acetic acid. Specify the acidic hydrogen atom. Explain its acidity (choose one version in the Answer Sheet).*

On the plot below an energy profile of the intramolecular proton transfer is given (the dependence of energy on the distance of proton motion (in nm)). Energy curve has a symmetric double-well form.

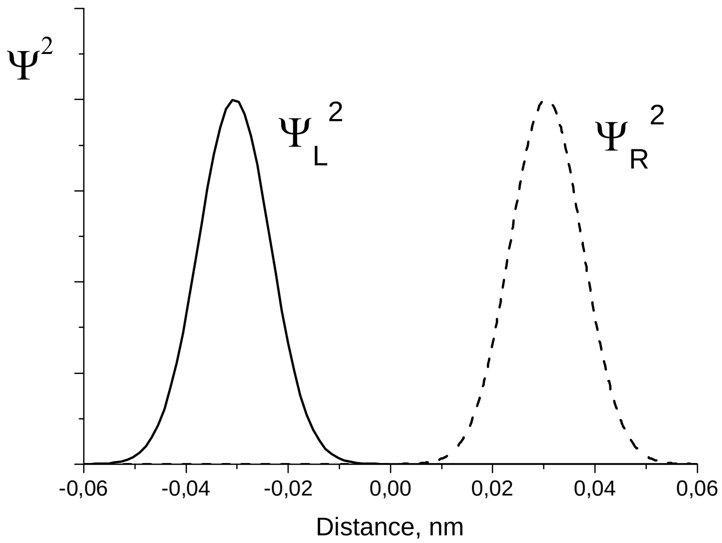


1.2.1 *Draw the structures corresponding to two minima on this curve.*

A proton is delocalized between two atoms and oscillates between two minima L and R with an angular frequency $\omega = 6.48 \cdot 10^{11}$ s^{-1}. Probability density for a proton depends on time as follows:

$$\Psi^2(x,t) = \frac{1}{2}\left[\Psi_L^2(x)+\Psi_R^2(x)+\left(\Psi_L^2(x)-\Psi_R^2(x)\right)\cos\left(\omega t\right)\right],$$

wavefunctions $\Psi_L(x)$ and $\Psi_R(x)$ describe a proton localized in the left and right wells, respectively:



1.3.1 *Write down the expressions for the probability density at three moments: (a) t = 0, (b) t = π/(2ω), (c) t = π/ω. Sketch the graphs of these three functions.*

1.3.2 *Without calculations, determine the probability of finding the proton in the left well at t = π/(2ω).*

1.3.3 *How much time is required for a proton to move from one well to another? What is the proton mean speed during the transfer?*

1.3.4 *From the energy curve, estimate the uncertainty of the position of proton forming hydrogen bonds. Estimate the minimal uncertainty of the proton speed. Compare this value with that obtained in* ***1.3.3*** *and draw a conclusion about the proton tunneling (choose one of the versions in the Answer Sheet).*

Problem 2. NANOCHEMISTRY

8 points

Metals of the iron subgroup are effective catalysts of hydrogenation of CO (Fischer-Tropsch reaction)

$$CO + 3H_2 \xrightarrow{\text{Fe, Co}} CH_4 + H_2O$$

Catalyst (e.g. cobalt) is often used in the form of solid nanoparticles that have a spherical structure (fig.1). The reduction in size of the catalyst increases catalytic activity significantly. The unwanted side-reaction however involves the oxidation of the catalyst:

$$Co(s) + H_2O\text{ (gas)} \rightleftharpoons CoO(s) + H_2\text{ (gas)} \qquad (1)$$

Solid cobalt oxide (bulk) is formed in the reaction vessel. This causes an irreversible loss of the catalyst's mass. Solid cobalt oxide can also be deposited on the surface of Co(s). In this case the new spherical layer is formed around the surface of the catalyst (see figure 2) and the catalytic activity drops.

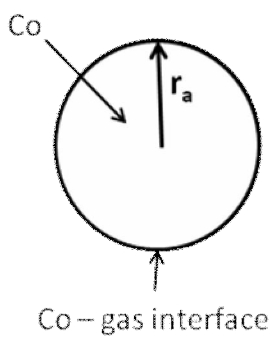


Fig. 1

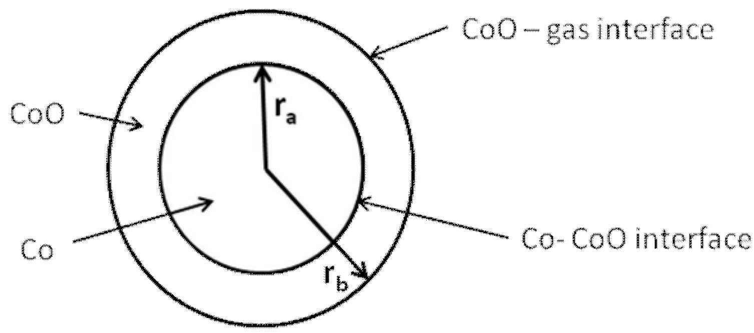


Fig. 2

Let us see how formation of nanoparticles affects the equilibrium of reaction (1). Useful equation:

$$G^0(r) = G^0(\text{bulk}) + \frac{2\sigma}{r}V$$

2.1.1 *Calculate the standard Gibbs energy* $\Delta_r G^0(1)$ *and the equilibrium constant for the reaction (1) at T = 500 K.*

2.1.2 *Calculate the equilibrium constant for reaction (1) when the cobalt catalyst is dispersed in the form of spherical particles (Fig.1) of radius*

(a) 10^{-8} m,·

(b) 10^{-9} m.

The surface tension at the Co-gas interface is 0.16 J/m^2. CoO forms a bulk phase.

The mixture of gases involved in the Fischer-Tropsch reaction (CO, CH_4, H_2, H_2O) was put into a reaction vessel containing the cobalt catalyst. The total pressure is p = 1 bar, temperature is T = 500 K. The mole fraction of hydrogen (%) in the mixture is 0.15%.

2.2.1 *At what minimum mole fraction of water (%) in the gas mixture the unwanted spontaneous oxidation of the catalyst becomes possible so that solid bulk CoO may appear in the system? Assume that cobalt catalyst is in the form of*

(a) a bulk phase

(b) spherical nanoparticles with r_a = 1 nm (Fig. 1).

2.2.2 *What would you suggest to protect Co nanoparticles from the spontaneous oxidation with the formation of bulk CoO at a constant ratio* $p(H_2O)/p(H_2)$ *and a constant temperature:*

(a) to increase r_a;

(b) to decrease r_a;

(c) change of r_a has no effect.

Assume now that solid cobalt oxide forms a spherical layer around a nanoparticle of cobalt. In this case the nanoparticle contains both a reactant (Co) and a product (CoO) (fig. 2). In the following problems denote surface tensions as $\sigma_{CoO\text{-}gas}$, $\sigma_{CoO\text{-}Co}$, radii as r_a, r_b, molar volumes as V(Co); V(CoO).

2.3.1 *Write down the expression for the standard molar Gibbs function of CoO.*

2.3.2 *Write down the expression for the standard molar Gibbs function of Co.*

Hint. If two spherical interfaces surround a nanoparticle, the excess pressure at its centre is given by the expression

$$P_{\text{in}} - P_{\text{ex}} = \Delta P = \Delta P_1 + \Delta P_2 = 2\frac{\sigma_1}{r_1} + 2\frac{\sigma_2}{r_2}$$

r_i, σ_i are radius and surface tension at the spherical interface *i,* respectively.

2.3.3 *Express the standard Gibbs energy of the reaction (1)* $\Delta_r G^0(1, r_a, r_b)$ *in terms of* $\sigma_{CoO\text{-}gas}$, $\sigma_{CoO\text{-}Co}$, r_a, r_b, *V(Co); V(CoO) and* $\Delta_r G^0(1)$.

2.3.4 *When spontaneous oxidation of Co begins the radii of two layers in the nanoparticle (Fig. 2) are almost equal,* $r_a = r_b = r_0$, *and* $\Delta_r G^0(1, r_a, r_b) = \Delta_r G^0(1, r_0)$. *Assume that* $\sigma_{\text{CoO-gas}} = 2\sigma_{\text{CoO-Co}}$. *Which plot in the Answer Sheet describes correctly the dependence of* $\Delta_r G^0(1, r_0)$ *on* r_0*?*

2.3.5 *What would you choose to protect Co nanoparticles from the spontaneous formation of the external layer of CoO at a constant ratio* $p(\text{H}_2\text{O})/p(\text{H}_2)$ *and a constant temperature:*

a) increase r_0

b) decrease r_0

c) change of r_0 *has no effect.*

Reference data:

Substance	ρ, g/cm^3	$\Delta_f G^\circ_{500}$, kJ/mol
Co (s)	8.90	
CoO (s)	5.68	–198.4
H_2O (gas)		–219.1

Problem 3. UNSTABLE CHEMICAL REACTIONS

7 points

Many chemical reactions display unstable kinetic behavior. At different conditions (concentrations and temperature) such reactions can proceed in various modes: stable, oscillatory or chaotic. Most of these reactions include autocatalytic elementary steps.

Consider a simple reaction mechanism involving autocatalytic step:

$$B + 2X \xrightarrow{k_1} 3X$$
$$X + D \xrightarrow{k_2} P$$

(B and D are reagents, X is an intermediate and P is a product).

3.1.1 *Write down the overall reaction equation for this two-step mechanism. Write the rate equation for X.*

3.1.2 *Deduce a rate equation using steady-state approximation. Find the orders:*

(i) a partial reaction order with respect to B;

(ii) a partial reaction order with respect to D;

(iii) the overall order of a reaction.

Let the reaction occur in an open system where reagents B and D are being continuously added to the mixture so that their concentrations are maintained constant and equal: [B] = [D] = const.

3.2.1 *Without solving the kinetic equation draw the kinetic curve [X](t) for the cases: 1)* $[X]_0 > k_2/k_1$; *2)* $[X]_0 < k_2/k_1$.

3.2.2 *Without solving the kinetic equation draw the kinetic curve [X](t) for the case when the reaction proceeds in a closed vessel with the initial concentrations:* $[B]_0 = [D]_0$, $[X]_0 > k_2/k_1$.

Much more complex kinetic behavior is possible for the reactions with several intermediates. Consider a simplified reaction mechanism for cold burning of ethane in oxygen:

$$C_2H_6 + X + \ldots \xrightarrow{k_1} 2X$$

$$X + Y \xrightarrow{k_2} 2Y + \ldots$$

$$C_2H_6 + Y + \ldots \xrightarrow{k_3} 2P$$

Under specific conditions this reaction displays oscillatory behavior.

Intermediates are peroxide $C_2H_6O_2$ and aldehyde C_2H_4O, P is a stable product.

3.3.1 *Identify X, Y, and P. Fill the blanks in the reaction mechanism.*

Behavior of unstable reactions is often controlled by temperature which affects the rate constants. In the above oxidation mechanism oscillations of concentrations are possible only if $k_1 \geq k_2$. Parameters of the Arrhenius equations were determined experimentally:

Step	A, $cm^3 \cdot mol^{-1} \cdot s^{-1}$	E_A, $kJ \cdot mol^{-1}$
1	$1.0 \cdot 10^{11}$	90
2	$3.0 \cdot 10^{12}$	100

3.4.1 *What is the highest temperature at which oscillatory regime is possible? Show your calculations.*

Problem 4. DETERMINATION OF WATER BY FISCHER TITRATION

8 points

Determination of water by the classical Fischer method involves titration of a sample solution (or suspension) in methanol by a methanolic iodine solution, containing also an excess of SO_2 and pyridine (C_5H_5N, Py) – Fischer reagent. The following reactions occur during the titration:

$$SO_2 + CH_3OH + H_2O + I_2 = 2HI + CH_3OSO_3H$$
$$Py + HI = PyH^+I^-$$
$$Py + CH_3OSO_3H = PyH^+CH_3OSO_3^-$$

Iodine content is usually expressed in mg of water reacting with 1 mL of the titrant solution (hereunder *T,* mg/mL), which equals the mass of water (mg) reacting with 1.00 mL of the iodine solution. *T* is determined experimentally by titration of a sample with a known water content. The sample may be, for example, a hydrated compound or a standard solution of water in methanol. In the latter case it should be taken into account that methanol itself can contain certain amount of water.
In all calculations please use the atomic masses accurate to 2 decimal points.

4.1 *Sometimes titration of water is performed in pyridine medium without methanol. How would the reaction of I_2 with SO_2 and H_2O occur in this case? Write down balanced reaction equation.*

Calculate the T values of iodine solution in each of the following cases:

4.2.1 *12.20 mL of Fischer reagent solution were used for titration of 1.352 g of sodium tartrate dihydrate $Na_2C_4H_4O_6{\cdot}2H_2O$.*

4.2.2 *A known amount of water (21.537 g) was placed into a 1.000 L volumetric flask which was filled by methanol up to the mark. For titration of 10.00 mL of the obtained solution, 22.70 mL of Fischer reagent solution were needed, whereas 2.20 mL of Fisher regent solution were used for titration of 25.00 mL of methanol.*

4.2.3 *5.624 g of water were diluted by methanol up to a total volume of 1.000 L (solution* ***A****); 22.45 mL of this solution were used for titration of 15.00 mL of a Fischer reagent (solution* ***B****).*

Then 25.00 mL of methanol (of the same batch as used for the preparation of solution **A**) and 10.00 mL of solution **B** were mixed, and the mixture was titrated by the solution **A**. 10.79 mL of the latter solution were spent.

4.3 *An inexperienced analyst tried to determine water content in a sample of CaO using Fischer reagent. Write down the equation(s) of reaction(s) demonstrating possible sources of errors.*

For the titration of 0.6387 g of a hydrated compound $Fe_2(SO_4)_3 \cdot xH_2O$, 10.59 mL of iodine solution (T = 15.46 mg/mL) were consumed.

4.4.1 *What other reaction(s), beside those given in the problem, can occur during the titration? Write down the equations of two such processes.*

4.4.2 *Write down an equation of the overall reaction of* $Fe_2(SO_4)_3 \cdot xH_2O$ *with the Fischer reagent.*

4.4.3 *Calculate the composition of the hydrate* $Fe_2(SO_4)_3 \cdot xH_2O$ *(x = integer).*

Problem 5. A MYSTERIOUS MIXTURE (ORGANIC HIDE-AND-SEEK GAME)

7.5 points

An equimolar mixture **X** of three colorless organic liquids **A**, **B**, **C** was treated by water with a drop of hydrochloric acid at heating to give, after separation from water, a 1:2 (molar ratio) mixture of acetic acid and ethanol without any other components. To the mixture after hydrolysis a catalytic amount (one-two drops) of concentrated sulfuric acid was added, and after long reflux (boiling with reflux condenser) a compound **D**, a volatile liquid with pleasant smell, was formed in 85% yield. Compound **D** is not identical to any of **A**, **B**, **C**.

5.1.1 *Draw the structure of compound **D**.*

5.1.2 *Which class of organic compounds does **D** belong to? Choose the proper variant from those given in the Answer Sheet.*

5.1.3 *Even if the reflux is continued twice as long, the yield of **D** would not exceed 85%. Calculate the expected yield of **D** if 1:1 (molar ratio) mixture of ethanol and acetic acid is taken. Assume that: a) volumes do not change during the reactions; b) all concomitant factors, such as solvent effects, non-additivity of volumes, variation of temperature, etc. are negligible. If you cannot make a quantitative estimate, please indicate whether the yield will be:*

a) the same (85%);

b) higher than 85%;

c) lower than 85%.

^{1}H NMR spectra of compounds **A**, **B**, **C** look very similar and each shows singlet, triplet and quartet with the ratio of integral intensities equal to 1:3:2.

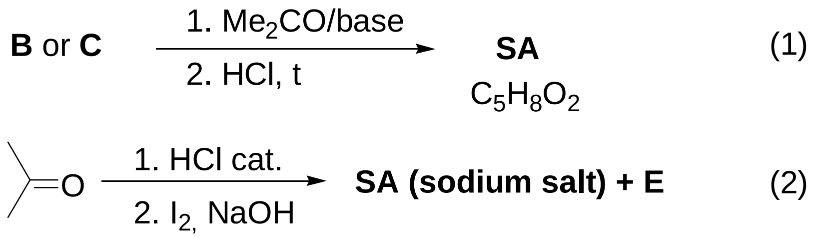
The same mixture **X** was subjected to alkaline hydrolysis. **A** remained unchanged, and was separated. The remaining solution after acidification and short boiling gave 2:3 (molar ratio) mixture of acetic acid and ethanol with evolution of gas.

The mixture **X** (3.92 g) was dissolved in diethyl ether and underwent hydrogenation in the presence of Pd on charcoal catalyst. 0.448 L (standard conditions) of hydrogen were absorbed, but after the reaction **A** and **C** were isolated unchanged (3.22 g of mixture were recovered) while neither **B**, nor any other organic compounds except diethyl ether could be identified after hydrogenation.

5.2.1 *Determine and draw the structures of **A**, **B**, and **C**.*

5.2.2 *Which intermediate compounds are formed during the acidic hydrolysis of **C**, and basic hydrolysis of **B**.*

The reaction of either **B** or **C** with acetone (in the presence of a base) with subsequent acidification by dilute HCl at gentle heating gives the same product, senecioic acid (**SA**), a compound widely occurring in Nature. Alternatively, senecioic acid can be obtained from acetone by treating it with concentrated HCl and subsequent oxidation of the intermediate product by iodine in alkaline solution. The latter reaction gives, besides sodium salt of senecioic acid, a heavy yellow precipitate **E** (see the scheme 2).



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

5.3.2 *Give the structure of **E**.*

Problem 6. SILICATES AS THE BASE OF THE EARTH CRUST

7 points

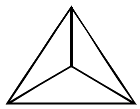
Silica and compounds derived from it, silicates, constitute ca. 90 % of the Earth crust substances. Silica gives rise to a beautiful material – glass. Nobody knows exactly how glass was discovered. There is a well-favored story related to Phoenician sailors who fused occasionally sea sand and soda ash. It is likely that they discovered the secret of "liquid glass" (LGL) – sodium metasilicate (Na_2SiO_3) soluble in water.

6.1.1 *The solution of LGL was used earlier as office glue. Write down the net ionic equation accounting for the ability of LGL to set in air.*

Hydrolysis of LGL in water allows obtaining a colloidal solution of silicic acid.

6.1.2 *Complete the Table in the Answer Sheet. 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.*

The structure of species occurring in aqueous solutions of silicates is rather complex. However, it is possible to distinguish the main building block of all species – ortho-silicate tetrahedron (SiO_4^{4-}, **1**):



(**1**)

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

6.2.1 *Determine the charge (n).*

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

6.2.3 *Depict its structure joining together several tetrahedra (**1**). Take into account that any adjacent tetrahedron shares one vertex.*

Charged monolayers with the composition $[Si_4O_{10}]^{m-}$ are found in kaolinite (clay).

6.2.4 *Using the same strategy as in **6.2.1-6.2.3**, depict <u>a fragment</u> of the layered structure joining 16 tetrahedra **(1)**. Note that 10 tetrahedra have shared vertices with 2 neighbors each, and the rest 6 have shared vertices with 3 neighbors each.*

Being placed into the LGL solution, salts of transition metals give rise to fancy “trees” tinted relevant to the color of the salt of the corresponding transition metal. Crystals of $CuSO_4{\cdot}5H_2O$ produce “trees” of blue color, whereas those of $NiSO_4{\cdot}7H_2O$ form green “trees”.

6.3.1 *Determine the pH of 0.1 M aqueous solution of copper sulfate at 25°C, assuming that its hydrolysis occurs in small degree only. Use the value of the first acidity constant of* $[Cu(H_2O)_4]^{2+}$ $K_a^I = 1{\cdot}10^{-7}$ *M*.

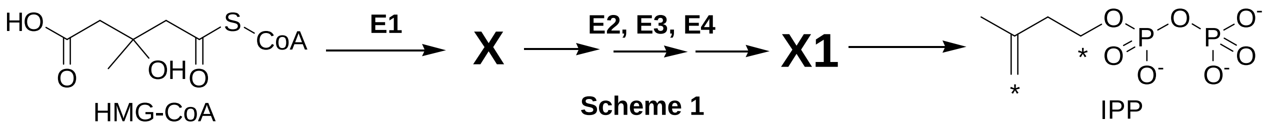
6.3.2 *Write down equation of a reaction between aqueous solutions of* $CuSO_4$ *and sodium metasilicate (LGL). Take into account the pH values of aqueous solutions of the salts.*

Problem 7. ATHEROSCLEROSIS AND INTERMEDIATES OF CHOLESTEROL BIOSYNTHESIS

7.5 points

Cholesterol is a lipid wide-spread in living nature. Disruption of its metabolism leads to atherosclerosis and related potentially fatal diseases.

Substances **X** and **Y** are two key intermediates of cholesterol biosynthesis in animals. **X** is an optically active monocarbonic acid composed of atoms of only three elements. It is formed in organisms from (*S*)-3-hydroxy-3-methylpentanedioyl-coenzyme A (HMG-CoA). This reaction is catalyzed by enzyme **E1** (which catalyses two types of reactions) and does not involve water as a substrate. **X** is further metabolized into **X1** through a three-stage process requiring enzymes **E2**, **E3**, **E4**, which catalyze reactions of one and the same (and only one) type. Finally, **X1** spontaneously (non-enzymatically) decomposes to give isopentenyl pyrophosphate (3-methylbut-3-enyl diphosphate, IPP) and inorganic products:

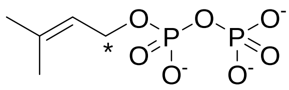


Scheme 1

7.1.1 *In the Answer Sheet, choose the reaction type(s) for **E1** and **E3**.*

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

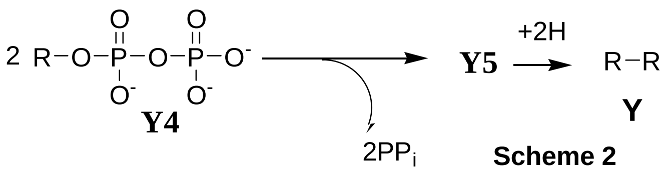
Y is an unsaturated acyclic hydrocarbon. Its reductive ozonolysis leads to a mixture of only three organic substances **Y1**, **Y2** and **Y3** in a molar ratio of 2:4:1. **Y** is formed as a result of a number of successive coupling reactions of two isomeric substances: IPP and dimethyl allyl pyrophosphate (3-methylbut-2-enyl diphosphate, DAP) with subsequent reduction of a double bond in the final coupling product **Y5**. Carbon atoms IPP and DAP involved in the formation of C–C bonds during biosynthesis of **Y** are marked with asterisks.



DAP

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

The product of the final coupling reaction (hydrocarbon **Y5**) is formed when two hydrocarbon residues (R) of intermediate **Y4** are combined:



Scheme 2

At each coupling stage but that shown in Scheme 2, pyrophosphate is released in a molar ratio of 1:1 to the coupling product.

7.2.2 *Determine molecular formula of* ***Y****, if it is known that* ***Y2*** *and* ***Y3*** *contain 5 and 4 carbon atoms, respectively.*

7.2.3 *Calculate the number of IPP and DAP molecules needed to give* ***Y5****, if it is known that all carbon atoms of isomeric pyrophosphates are incorporated into* ***Y****.*

7.2.4 *Draw the product of coupling reaction of one IPP molecule with one DAP molecule (C–C bond can be formed only by carbon atoms marked with asterisks), if it is known that subsequent reductive ozonolysis of the product of the coupling reaction gives* ***Y1****,* ***Y2*** *and one more product, the latter containing phosphorus.*

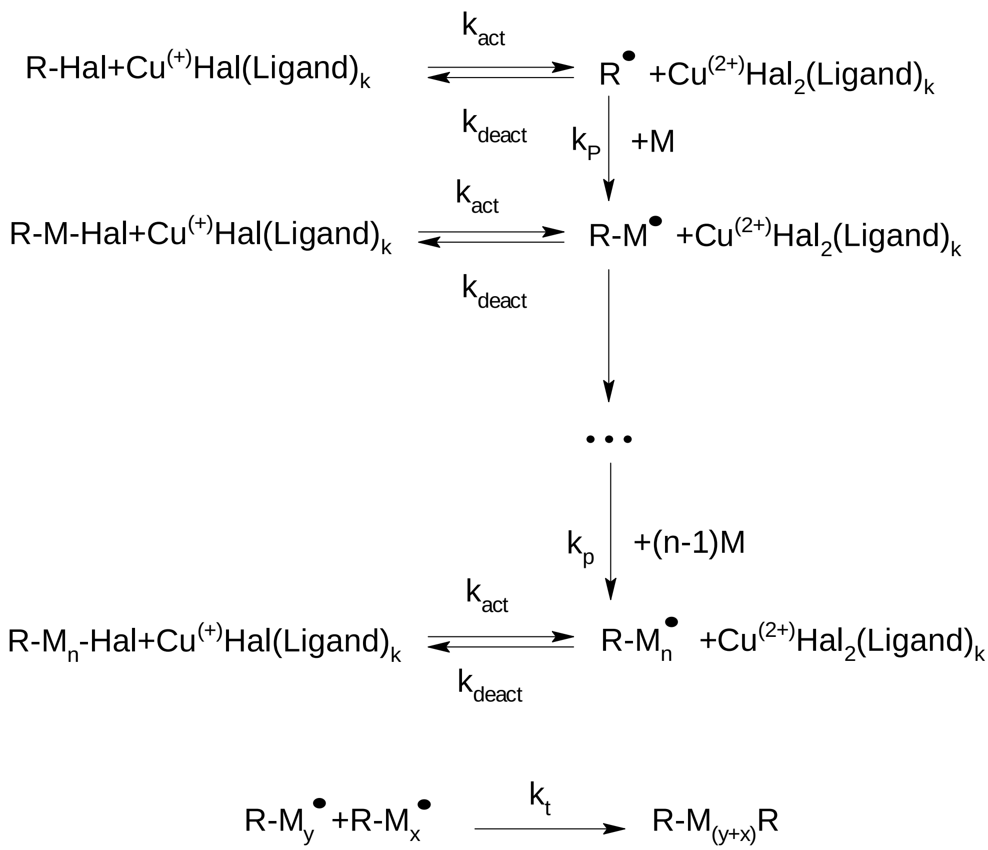
The only double bond reduced in **Y5** during its metabolism into **Y** was formed in the reaction described in Scheme 2. All double bonds in **Y** and **Y4** exist in *trans* configuration.

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

Problem 8. ATRP ALLOWS NEW POLYMERS

8 points

ATRP (Atom Transfer Radical Polymerization) is one of the most promising novel approaches towards polymer synthesis. This modification of radical polymerization is based on a redox reaction of organic halides with complexes of transition metals, Cu (I) in particular. The process can be described by the following scheme (M – monomer, Hal – halogen):



The reaction rate constants are: k_{act} – all activation reactions, k_{deact} – all reversible deactivation reactions, k_p – chain propagation, and k_t – irreversible termination.

8.1.1 *Write down the expressions for the rates of ATRP elementary stages: activation (v_{act}), deactivation (v_{deact}), propagation (v_p) and termination (v_t). Write down generalized equation assuming just one reacting species R'X, where R' means any of R- or R-M_n- and X means Hal.*

Consider that the total number of polymeric chains is equal to that of initiator molecules. Assume that at each moment throughout polymerization all chains are of the same length.

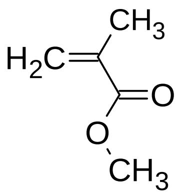
8.1.2 *Compare the rate of deactivation to the rates of ATRP elementary stages.*

Dependence of monomer concentration ([M]) on reaction time (t) for ATRP is:

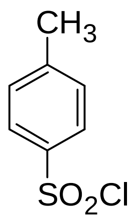
$$\ln\left(\frac{[M]}{[M]_0}\right) = -k_p \cdot [R^{\cdot}] \cdot t \,,$$

$[M]_0$ – the initial monomer concentration, k_p – the rate constant of propagation, $[R^{\cdot}]$ – the concentration of active radicals.

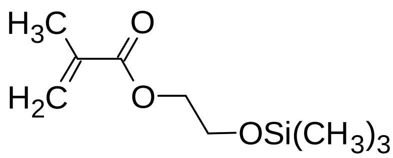
To prepare a polymer sample by using ATRP, catalytic amounts of CuCl, organic ligand (L) and 31.0 mmol of monomer (methylmethacrylate, or MMA) were mixed. The reaction was initiated by adding 0.12 mmol of tosyl chloride (TsCl). Polymerization was conducted for 1400 s. k_p is 1616 $L \cdot mol^{-1} s^{-1}$, and the steady state concentration of radicals is $1.76 \cdot 10^{-7}$ $mol \cdot L^{-1}$.



MMA



TsCl



HEMA-TMS

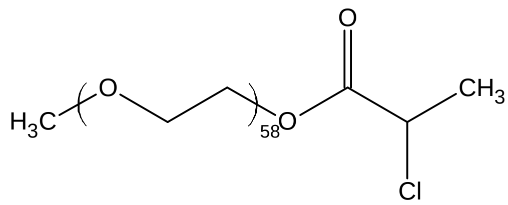
8.2.1 *Calculate the mass (m) of the polymer obtained.*

In another experiment the time of MMA polymerization was changed, all the rest reaction conditions being the same. The mass of the obtained polymer was 0.73 g. Then 2-(trimethylsilyloxy)ethyl methacrylate, HEMA-TMS (23.7 mmol) was added to the mixture and polymerization was continued for another 1295 s. MMA and HEMA-TMS reactivities are the same under reaction conditions.

8.2.2 *Calculate the degree of polymerization (DP) of the obtained polymer.*

8.2.3 *Depict the structure of the obtained polymer (including end groups), showing MMA and HEMA-TMS units as A and B, respectively. If necessary, use the symbols in the copolymer structure representation:* block *(block),* stat *(statistical),* alt *(alternating),* grad *(gradient),* graft *(grafted). For example, (A_{65}-graft-C_{100})-stat-B_{34} means that chains of polymer C are grafted on units A in the statistic copolymer of A and B.*

ATRP was applied to synthesize two block copolymers, P1 and P2. One block in both block-copolymers was the same and was synthesized from mono-(2-chloropropionyl)-polyethylene oxide used as a macroinitiator:



The other block in P1 consisted of styrene (C), and in P2 of *p*-chloromethylstyrene (D) units.

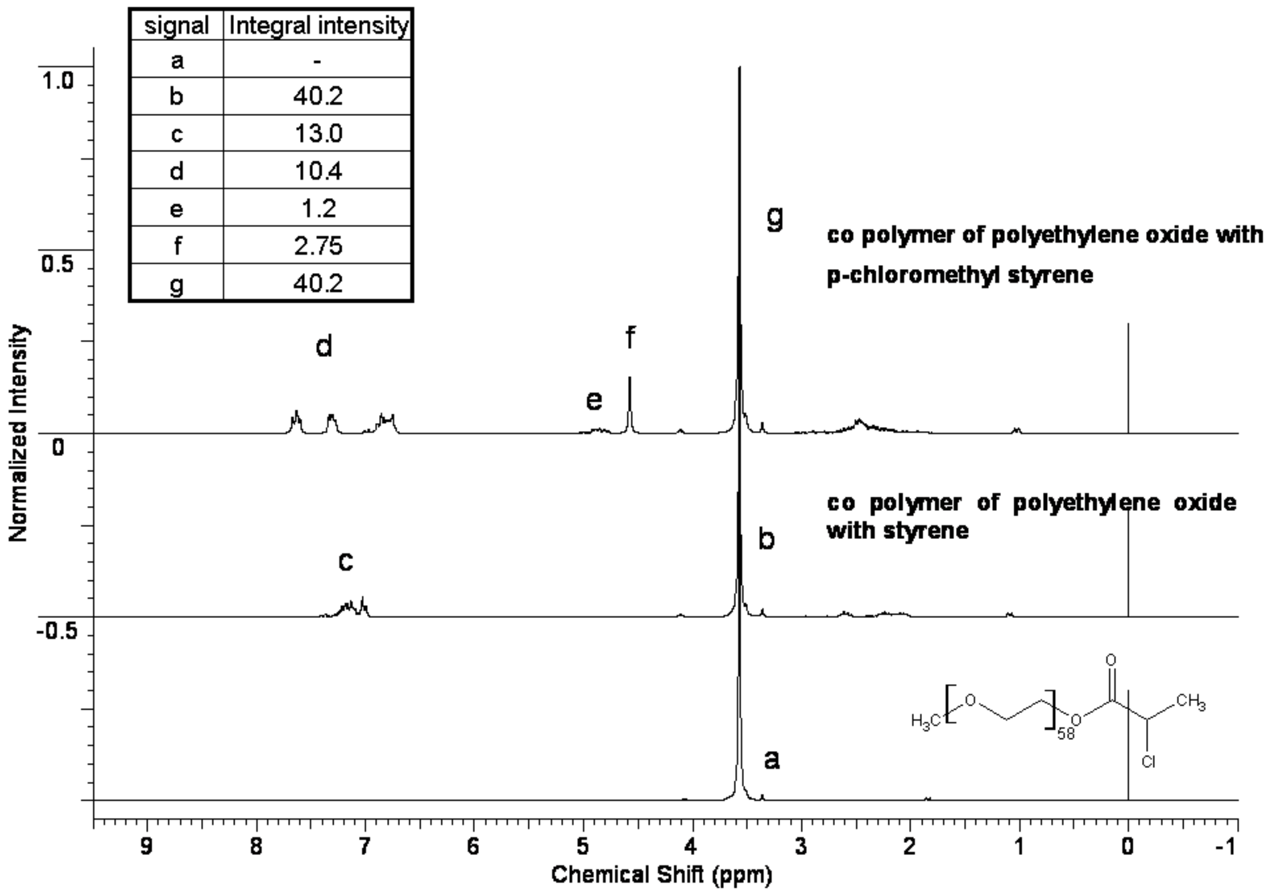
^{1}H NMR spectra of the macroinitiator, P1 and P2 are given below. Integral intensities of characteristic signals can be found in the table.

8.3.1 *Assign ^{1}H NMR signals to the substructures given in the Answer Sheet.*

8.3.2 *Determine the molar fractions of units C and D and the molecular masses of P1 and P2.*

8.3.3 *Write down all possible reactions of activation occurring during the synthesis of P1 and P2. You may use R symbol to depict any unchanged part of the macromolecule, but you should specify what substructure you use it for.*

8.3.4 *Draw the structure of P1 and one of possible structures of P2 representing poly(ethylene oxide) chain by a wavy line and showing units of co-monomers as C and D, respectively.*



signal | Integral intensity
a | -
b | 40.2
c | 13.0
d | 10.4
e | 1.2
f | 2.75
g | 40.2
co polymer of polyethylene oxide with p-chloromethyl styrene
co polymer of polyethylene oxide with styrene
Normalized Intensity
Chemical Shift (ppm)

ANSWER SHEETS, SOLUTIONS, AND GRADING SCHEMES

PRACTICAL PROBLEMS

Problem 1. ION-EXCHANGE CHROMATOGRAPHY OF AMINO ACIDS

Question	1a	1b	1c	2-3	4	Total		**Points**
Marks	9	0	3	72	2	86		**20**

Number of the given mixture of amino acids ________ (A number between 301 and 600)

1.1a *Draw the profile of coloration intensity on the plate sketch.*

1.1b *Indicate changes of eluents by drawing lines between the corresponding wells.*

	1	2	3	4	5	6	7	8	9	10	11	12
A	○	○	○	○	○	○	○	○	○	○	○	○
B	○	○	○	○	○	○	○	○	○	○	○	○
C	○	○	○	○	○	○	○	○	○	○	○	○
D	○	○	○	○	○	○	○	○	○	○	○	○
E	○	○	○	○	○	○	○	○	○	○	○	○
F	○	○	○	○	○	○	○	○	○	○	○	○
G	○	○	○	○	○	○	○	○	○	○	○	○
H	○	○	○	○	○	○	○	○	○	○	○	○

1.1c *Labels of wells corresponding to the chosen fractions.*

Peak number	Labels of wells
1	
2	
3	

1.2-1.3 *Content (in mg) of each amino acid in the amino acid mixture you were given.*

Your work

Complete the table.

Peak number	Volume of combined fractions, *mL*	Amino acid (3-letter code)	Wavelength λ, *nm*	Absorbance A_λ	Amino acid mass in the given mixture, *mg*
1					
2					
3					

ATTENTION. The print-offs with the spectra of your samples should be put into the envelope and delivered at the end of examination alongside with the Answer Sheets.

1.4 *Resonance structures of the substance responsible for the mixture coloration.*

Solution and grading scheme

1.1a 3 marks for each peak if at least two blank wells between peaks
9 marks maximum.

1.1b Not graded.

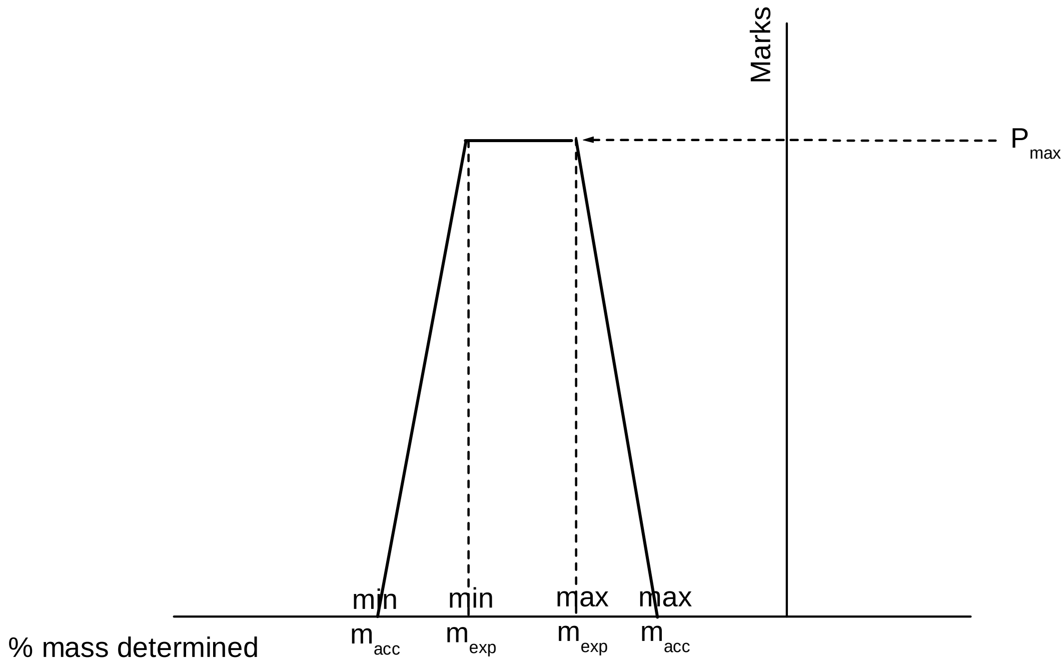
1.1.c 1 point for each proper choice. Combined mixtures should include all fractions identified as “2” and “3” and should be free of fractions without amino acids. Fractions identified as “1” may be or may be not included.
3 marks maximum.

1.2-1.3

Content of an amino acid = $\frac{A_\lambda \cdot n \cdot V \cdot M_W}{\varepsilon \cdot l}$,

A_λ is the absorbance of the sample calculated from the spectra, l is the optical length (1.0 cm), *n* is the dilution factor determined as a ratio of the aliquot of analyzing solution (0.1 mL) and the final volume of the sample in the cuvette, *V* is the volume of the combined fraction from the corresponding peak, and M_W is the molar mass of the amino acid.
3 marks for correct formula,
3 marks for correct determination of optical densities (1 mark for each assay)
1 mark penalty for miscalculation.

Content of each amino acid is determined by using the following plot (values recalculated from volumes reported by students and absorbance values recorded by spectrophotometer)



Scoring:

m < min m_{acc} OR m > max m_{acc} — 0 marks

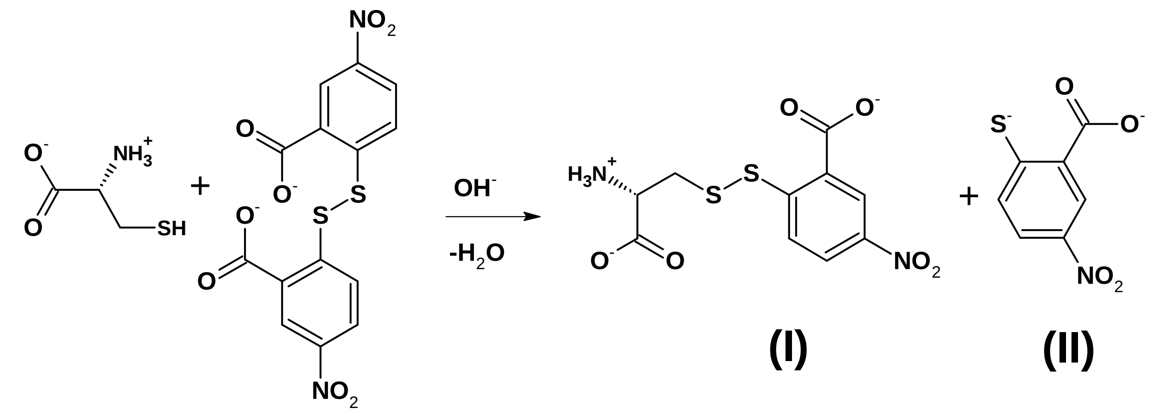
min m_{acc} < m < min m_{exp} — $P_{max}\dfrac{(m - \min m_{acc})}{(\min m_{exp} - \min m_{acc})}$ marks

min m_{exp} < m < max m_{acc} — P_{max} marks

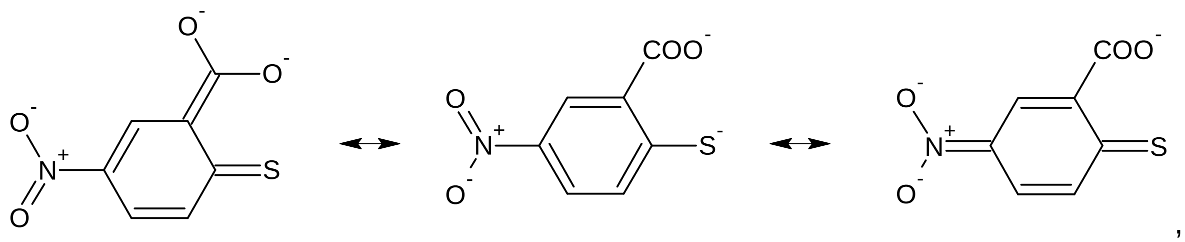
Amino acid	Min m_{acc}/m_{exact} ·100%	Min m_{exp}/m_{exact} ·100%	Max m_{exp}/m_{exact} ·100%	Max m_{acc}/m_{exact} ·100%	P_{max}
Cys	70%	85%	110%	115%	22
His	60%	85%	110%	115%	22
Arg	25%	45%	65%	85%	22

<u>72 marks maximum</u>

1.4 As it is given in the task text, mixed disulfide and 2-thio-5-nitrobenzoic acid are formed in the reaction.



Under slightly alkaline conditions, thiol group of (**II**) dissociates, and thiophenolate-anion is formed. Resonance structures can be realized for this compound:



The electronic structure of asymmetrical disulfide (**I**) does not differ considerably from that of the original Ellmann reagent. Therefore, it can be concluded that the compound responsible for coloration is thiophenolate-anion (a form containing C=S bond).

2 marks for three correct ionized structures, one of which contains C=S bond
1 mark for three other structures, all without C=S bond
1 mark for less than three structures, one of which contains C=S bond.
<u>2 marks maximum.</u>

Problem 2. DETERMINATION OF CARBONATE AND HYDROGEN PHOSPHATE IN AN ABRASIVE SAMPLE

Question	1a	1b	2	3	4	5	6a	6b	Total		Points
Marks	25	5	25	25	5	5	1	9	100		**20**

2.1a *Standardization of NaOH solution*

Titration No	Initial burette reading, mL	Final burette reading, mL	Volume of NaOH solution consumed (V_1), mL
1			
2			
3			
Final volume of NaOH solution ($V_{1,f}$), mL			

2.1b *Calculation of NaOH concentration*

Your work

c(NaOH) = __________ mol/L

2.2 *The first titration of the sample (BCG)*

Titration No	Initial burette reading, mL	Final burette reading, mL	Volume of NaOH solution consumed (V_2), mL
1			
2			
3			
Final volume of NaOH solution ($V_{2,f}$), mL			

2.3 *The second titration of the sample (TP)*

Titration No	Initial burette reading, mL	Final burette reading, mL	Volume of NaOH solution consumed (V_3), mL
1			
2			
3			
Final volume of NaOH solution ($V_{3,f}$), mL			

2.4 *Calculation of the mass of* CO_3^{2-}

Your work

$m(CO_3^{2-})$ = __________ g

2.5 *Calculation of the mass of* HPO_4^{2-}

Your work

$m(HPO_4^{2-})$ = __________ g

Additional questions

2.6a *Indicate one reaction (write down the equation) for a process interfering in the sample analysis you have carried out in the presence of* Ca^{2+}.

2.6b *A list of mistakes possible at different steps is given in the table. Indicate which of the mistakes can lead to errors in CO_3^{2-} and/or HPO_4^{2-} content determination. Use the following symbols: "0" if no error is expected, "+"or "–" if the result is higher (positive error) or lower (negative error) than the true one.*

Mistake	Step	Error	
		CO_3^{2-} content	HPO_4^{2-} content
Incomplete removal of CO_2	1		
Too large excess of $K_2C_2O_4$ on calcium precipitation	2		
Too late indication of the endpoint (overtitration) on NaOH standardization	3		
Insufficient washing of the filter at CaC_2O_4 filtration	4		
Overtitration of the sample against BCG	5		
Overtitration of the sample against TP	6		

H_2CO_3: $pK_{a1} = 6.35$; $pK_{a2} = 10.32$

$H_2C_2O_4$: $pK_{a1} = 1.25$; $pK_{a2} = 4.27$

Extra samples given or column broken

Problem No	Sample No	Column broken and replaced	Student's signature	Lab assistant's signature

Solution and grading scheme

2.1a, 2.2, 2.3 The values of the final volumes $V_{1,f}$, $V_{2,f}$, and $V_{3,f}$, (as reported in the Answer Sheet) are graded according to the following scheme:

$$\Delta V = |V_{reported} - V_{true}|,$$

$V_{reported}$ is either $V_{1,f}$, $V_{2,f}$, and $V_{3,f}$, V_{true} is the corresponding master value (will be given with the copies of students' works).

Value of ΔV	Marks
$\Delta V \le \Delta V_{expected}$	25
$\Delta V \ge \Delta V_{acceptable}$	0
$\Delta V_{expected} \le \Delta V \le \Delta V_{acceptable}$	$25\times\left(\dfrac{\Delta V_{acceptable}-\Delta V}{\Delta V_{acceptable}-\Delta V_{expected}}\right)$

The values of $\Delta V_{expected}$ and $\Delta V_{acceptable}$ (in mL) are listed in the table below.

	ΔV, mL	
	expected	acceptable
$V_{1,f}$	**0.10**	**0.25**
$V_{2,f}$	**0.15**	**0.40**
$V_{3,f}$	**0.15**	**0.40**

<u>25 marks maximum for each titration</u>

2.1b *Calculation of NaOH concentration*

$$c(\text{NaOH}) = \frac{c(HCl)\times V(HCl)\times V(aliquot)}{V(flask)\times V(NaOH)} = \frac{1.214\ (mol/L)\times 10.00(mL)\times 10.00(mL)}{100.0(mL)\times V_{1,f}\,(mL)} =$$

2.4 *Calculation of the mass of CO_3^{2-}*

$$m(CO_3^{2-})\ (g) = M(CO_3^{2-})\times 1/2\times\frac{c(NaOH)\times(V_{1,f}-V_{3,f})\times V(flask)}{V(aliquot)} =$$

$$= 60.01\ (g/mol)\times 1/2\times\frac{c(NaOH)\ (mol/L)\times(V_{1,f}-V_{3,f})\ (mL)\times 100.0\ (mL)}{10.00\ (mL)}\times 0.001\,(L/mL) =$$

2.5 *Calculation of the mass of HPO_4^{2-}*

$$m(HPO_4^{2-})\ (g) = M(HPO_4^{2-})\times\frac{c(NaOH)\times(V_{3,f}-V_{2,f})\times V(flask)}{V(aliquot)} =$$

$$= 95.98\ (g/mol)\times\frac{c(NaOH)\ (mol/L)\times(V_{3,f}-V_{2,f})\ (mL)\times 100.0\ (mL)}{10.00\ (mL)}\times 0.001\,(L/mL) =$$

2.1b, 2.4, 2.5

Correctness of calculations is graded by:

1) comparing the numerical result (including the number of significant figures) reported by a student with that obtained **from the student's data** using correct method of calculation;
2) checking out the a student's way of calculation.

5 marks maximum for completely correct calculation of each value

Penalty for errors in calculations or data presentation.

	Error type	Penalty marks (for calculation of each value)
1	Incorrect method of calculation	–5
2	Mistakes in dilution factor	–1
3	Confusion between units of measurement	–1
4	Mistake in stoichiometric (equivalency) relationships	–1
5	More or less than 4 significant figures in *c*(NaOH)	–0.5*
6	More than 4 or less than 3 significant figures in *m*(CO_3^{2-}) and *m*(HPO_4^{2-})	–0.5*
7	Rounding errors affecting the 1st or 2nd significant figures in the final result	–0.5**
8	Miscalculations and slips	–0.2 per error

*Only the number of significant figures in the final answer is taken into account.
Not applied if the error originates from insufficient number of significant figures in previously calculated *c*(NaOH). **No double penalty!

2.6a

$$Ca^{2+} + H_2PO_4^- \rightarrow CaHPO_4 + H^+$$

or

$$3Ca^{2+} + 2HPO_4^{2-} \rightarrow Ca_3(PO_4)_2 + 2H^+$$

In course of these processes free protons evolve influencing the results of titration.
1 mark if the Answer Sheet contains at least one correct reaction equation. Incorrect equations are not penalized.

2.6b

Mistake	Error	
	CO_3^{2-} content	HPO_4^{2-} content
Below pH 4.5 (first endpoint, V_2) H_2CO_3 is not titrated Between pH 4.5 and 10 (second endpoint, V_3) H_2CO_3 is titrated **Thus, increase of V_3 ; V_1 and V_2 unchanged**	–	+
No influence, $C_2O_4^{2-}$ is too weak base	0	0
Increase of V_1 and proportional decrease of c(NaOH) [as c(NaOH)V_1 is equivalent to the initial amount of standard HCl and so remains constant]**; V_2 and V_3 unchanged**	–	–
Losses of sample leads to proportional **decrease of V_2 and V_3 and therefore V_3-V_2; V_1 unchanged**	+	–
Increase of V_2, V_1 and V_3 unchanged	0	–
Increase of V_3, V_1 and V_2 unchanged	–	+

THEORETICAL PROBLEMS

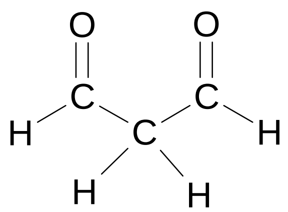
Problem 1. PROTON TUNNELING

Question	1.1	1.2	2.1	3.1	3.2	3.3	3.4	Total		**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

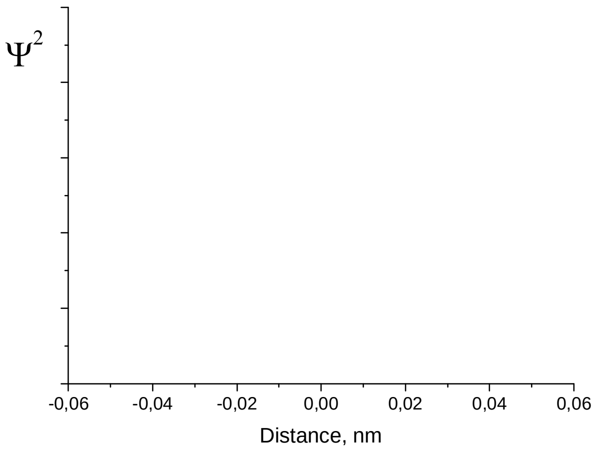
The correct answer ________

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

1.3.1 *The probability density*

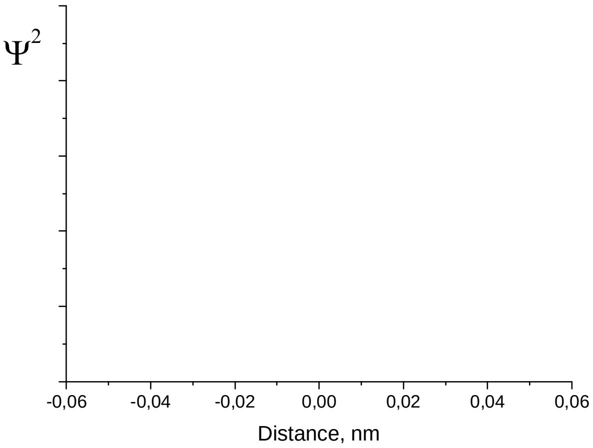
(a) $t = 0$

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



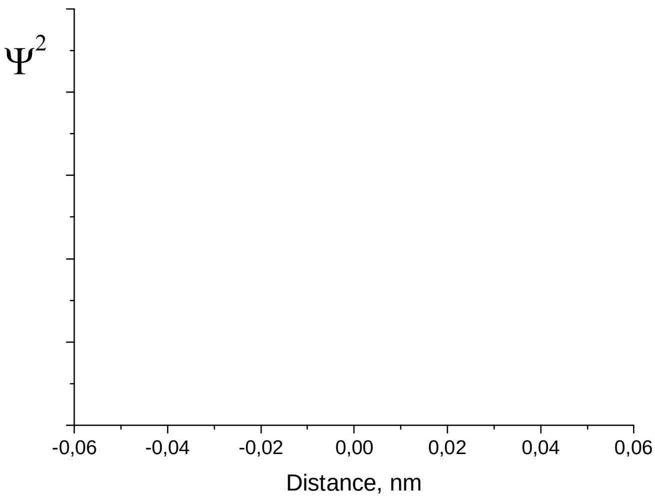
(b) $t = \pi/(2\omega)$

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



(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*

Δx =

The minimal uncertainty of proton velocity

Your work:
Δv =

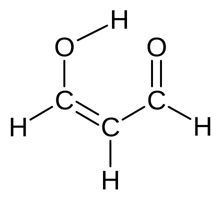
a) Proton is a rather heavy particle, and its tunneling in malonaldehyde can be described in classical terms of position and velocity
b) Proton tunneling is a purely quantum effect; it cannot be described in classical terms
c) Uncertainty of proton velocity is so large that tunneling cannot be observed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

The correct answer is _______

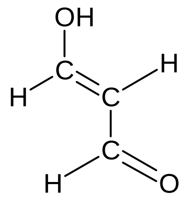
Solution and grading scheme

1.1.1 *The structures of propanedial and two of its isomers*

O=CH–CH_2–CH=O 1 mark



1 mark



1 mark

<u>3 marks maximum</u>

1.1.2

Acidic hydrogen atom is in CH_2 (in enol forms acidic hydrogen is in OH).

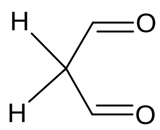
1 mark

Acidity of CH_2 group is caused by the stability of carbanion due to conjugation with two carbonyl groups. The first answer is correct.

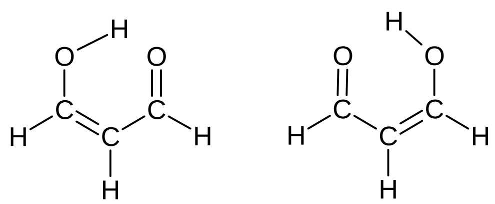
2 marks

<u>3 marks maximum</u>

1.2.1 The distance between two minima on the energy curve is 0.06 nm. In a purely aldehyde form



such distance between two possible positions of proton is impossible. Tunneling takes place only in enol Z-form:



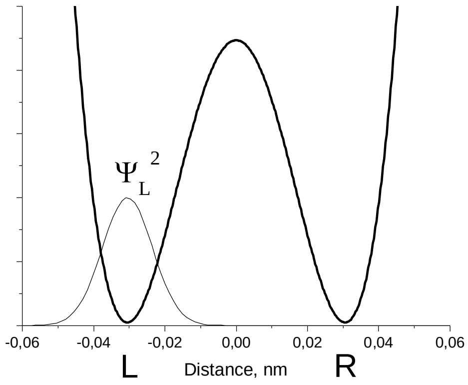
1 mark for each structure

<u>2 marks maximum</u>

1.3.1 *Expressions and plots of probability density*

(a) $\Psi^2(x,0) = \frac{1}{2}\left[\Psi_L^2(x) + \Psi_R^2(x) + \Psi_L^2(x) - \Psi_R^2(x)\right] = \Psi_L^2(x)$ 1 mark

The probability density is concentrated in the left well:

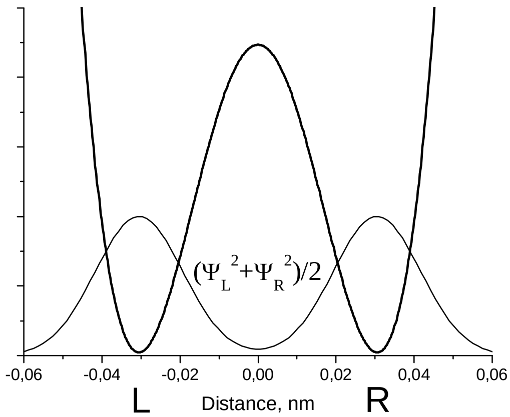


0.5 marks

(b) In the middle of the time interval

$$\Psi^2\left(x,\frac{\pi}{2\omega}\right) = \frac{1}{2}\left[\Psi_L^2(x)+\Psi_R^2(x)\right]$$ 1 mark

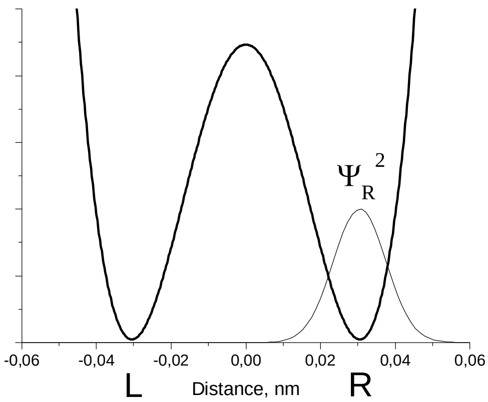
The probability density has a symmetric form, a proton is delocalized between two wells:



0.5 marks

(c) $$\Psi^2\left(x,\frac{\pi}{\omega}\right) = \frac{1}{2}\left[\Psi_L^2(x)+\Psi_R^2(x)-\Psi_L^2(x)+\Psi_R^2(x)\right] = \Psi_R^2(x)$$ 1 mark

The probability density is concentrated in the right well:



0.5 marks

<u>4.5 marks maximum</u>

1.3.2 *The probability of finding the proton in the left well* is 1/2, because probability function is symmetric, and both wells are identical.

2 marks

1.3.3 *The time of transfer* from one well to another is $t = \pi / \omega$.

$$t = \frac{3.14}{6.48 \cdot 10^{11}} = 4.85 \cdot 10^{-12} \text{ s.}$$ 2 marks

The proton velocity:

$$V = \frac{0.06 \cdot 10^{-9}}{4.85 \cdot 10^{-12}} = 12 \text{ m/s.}$$ 2 marks

<u>4 marks maximum</u>

1.3.4 *The uncertainty of proton position* is approximately equal to half of the distance between minima, that is 0.03 nm (<u>0.06 nm was also accepted</u>).

1 mark

The minimal uncertainty of velocity can be obtained from the uncertainty relation:

$$\Delta V = \frac{\hbar}{2m\Delta x} = \frac{1.055 \cdot 10^{-34}}{2 \cdot \frac{0.001}{6.02 \cdot 10^{23}} \cdot 0.03 \cdot 10^{-9}} \approx 1000 \text{ m/s.}$$ 3 marks

Comparing this uncertainty with the velocity 12 m/s we see that the notion of proton velocity during transfer from one well to another is senseless. Therefore, proton tunneling is a purely quantum phenomenon and cannot be described in classical terms. *The second conclusion is correct*.

2 marks

<u>6 marks maximum</u>

Problem 2. NANOCHEMISTRY

Question	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	3.5	Total	**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) =

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)*

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

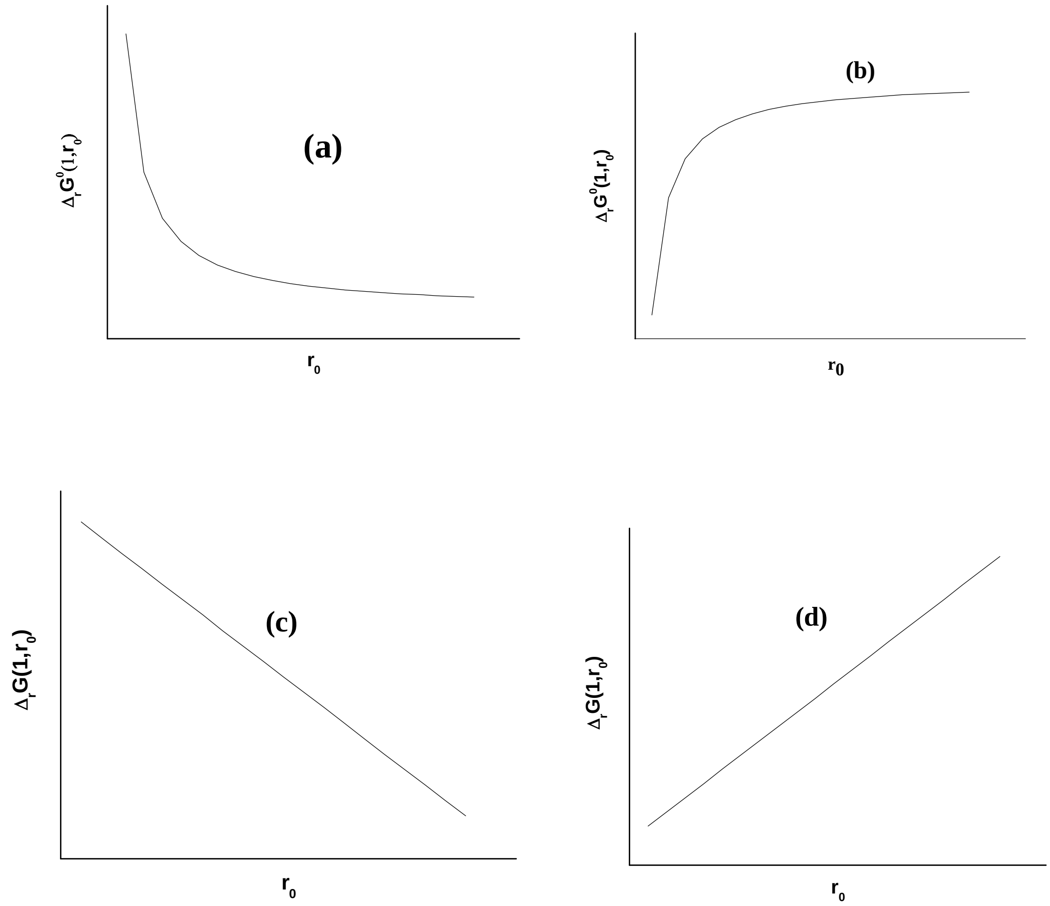
2.3.2 *Standard molar Gibbs function of Co (internal layer):*

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

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

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

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) ☐

Solution and grading scheme

2.1.1 The Gibbs energy and the equilibrium constant of reaction (1)

$$\Delta_r G^0_{500}(1) = \Delta G^0_{f,500}(\text{CoO,s}) - \Delta G^0_{f,500}(\text{H}_2\text{O,g}) = -198.4 + 219.1 = 20.7 \text{ kJ/mol}$$ 0.5 marks

$$K = e^{-\frac{\Delta_r G^0_{500}(1)}{RT}} = e^{-\frac{20700}{8.314 \cdot 500}} = 6.88 \cdot 10^{-3}$$ 0.5 marks

<u>1 mark maximum</u>

2.1.2 The standard Gibbs energy of the reaction (1) with the spherical cobalt nanoparticles of radius r_a is

$$\Delta_r G^\circ_{500}(1, r_a) = G^0_{bulk,500}(\text{CoO,s}) + G^0_{500}(\text{H}_2\text{,g}) - G^0_{500}(\text{H}_2\text{O,g}) - G^0_{sph}(\text{Co}) =$$

$$= G^0_{500}(\text{CoO,s}) + G^0_{500}(\text{H}_2\text{,g}) - G^0_{500}(\text{H}_2\text{O,gas}) - \left(G^0_{500}(\text{Co,s}) + \frac{2\sigma_{\text{Co-gas}} V(\text{Co})}{r_a} \right) =$$

$$= \Delta_r G^\circ_{500}(1) - \frac{2\sigma_{\text{Co-gas}} V(\text{Co})}{r_a};$$

$$V(\text{Co}) = \frac{M_{\text{Co}}}{\rho(\text{Co})} = \frac{10^{-6} \cdot 59.0}{8.90} = 6.6 \cdot 10^{-6} \ \frac{\text{m}^3}{\text{mol}};$$

for spherical particles with $r_a = 10^{-8}$, 10^{-9} m one gets, respectively

$$\frac{2\sigma_{\text{Co-gas}} V(\text{Co})}{r_a} = 210 \text{ and } 2100 \text{ J/mol.}$$

$\Delta_r G^\circ_{500}(1, r_a)$ is equal to 20.5 (a), and 18.6 (b) kJ/mol, respectively.

The equilibrium constant is calculated from the equation

$$K(1, r_a) = \exp\left(-\frac{\Delta_r G^\circ_{500}(1, r_a)}{RT} \right);$$

$K(1, r_a) = 7.22 \times 10^{-3}; \quad r_a = 10^{-8}$ m $\qquad$ $K(1, r_a) = 11.4 \times 10^{-3}; \quad r_a = 10^{-9}$ m

<u>2 marks maximum</u>

2.2.1 The standard Gibbs energy for reaction (1) involving nanoparticles of cobalt is

$$\Delta_r G^\circ_{500}(1, r_a) = \Delta_r G^\circ_{500}(1) - \frac{2\sigma_{\text{Co-gas}}}{r_a} V(\text{Co})$$

$\Delta_r G^\circ_{500}(1)$ is 20.7 kJ/mol. For spherical cobalt particles with r_a = 1 nm $\Delta_r G^\circ_{500}(1, r_a)$ is 18.6 kJ/mol. Solid cobalt oxide can be formed spontaneously when Gibbs energy of reaction (1) is negative. The inequality for bulk cobalt is:

$$\Delta_r G(1) = \Delta_r G^\circ_{500}(1) + RT \ln\left(\frac{p(\mathrm{H_2})}{p(\mathrm{H_2O})}\right) = \Delta_r G^\circ_{500}(1) - RT \ln\left(\frac{p(\mathrm{H_2O})}{p(\mathrm{H_2})}\right) \le 0$$

and for spherical cobalt nanoparticles with r_a = 1 nm:

$$\Delta_r G(1, r_a) = \Delta_r G^\circ_{500}(1, r_a) + RT \ln\left(\frac{p(\mathrm{H_2})}{p(\mathrm{H_2O})}\right) = \Delta_r G^\circ_{500}(1) - \frac{2\sigma_{\text{Co-gas}}}{r_a} V(\mathrm{Co}) - RT \ln\left(\frac{p(\mathrm{H_2O})}{p(\mathrm{H_2})}\right) \le 0$$

The minimum ratios $\frac{p(\mathrm{H_2O})}{p(\mathrm{H_2})}$ are 145.6 (a) and 87.7 (b), respectively.

The hydrogen pressure is

$$1 \text{ bar}\cdot 0.0015 = 1.5\cdot 10^{-3} \text{ bar}$$

The minimum pressures of water are

$1.5\cdot10^{-3}\cdot145.6$ = 0.218 bar (a) and $1.5\cdot10^{-3}\cdot87.7$ = 0.132 bar (b), for the bulk cobalt and for nanoparticles, respectively.

H_2O%(bulk Co) = 21.8% *H_2O%*(nanoparticles with $r_a = 1*10^{-9}$ m) = 13.2%.

We assume that bulk cobalt oxide is formed.

4 marks maximum

2.2.2 For the spontaneous oxidation

$$\Delta_r G(1, r_a) = \Delta_r G^\circ_{500}(1) - \frac{2\sigma_{\text{Co-gas}}}{r_a} V(\mathrm{Co}) - RT \ln\left(\frac{p(\mathrm{H_2O})}{p(\mathrm{H_2})}\right) \le 0$$

and

$$\Delta_r G^\circ_{500}(1) - \frac{2\sigma_{\text{Co-gas}}}{r_a} V(\mathrm{Co}) \le RT \ln\left(\frac{p(\mathrm{H_2O})}{p(\mathrm{H_2})}\right)$$

The left hand side of the last inequality becomes more positive with the increase of r_a. At certain point the inequality will be disturbed and the spontaneous oxidation will not take place. So, to protect cobalt nanoparticles from the spontaneous oxidation in this case one has to lengthen the radius r_a. The answer (a) is correct.

2 marks maximum

2.3.1 The equation for the standard molar Gibbs function of CoO (external layer) reads:

$$G^0_{sph}(\mathrm{CoO}, r_b) = G_{bulk}(\mathrm{CoO}) + \frac{2\sigma_{\text{CoO-gas}}}{r_b} V(\mathrm{CoO}) = G^\circ(\mathrm{CoO,s}) + \frac{2\sigma_{\text{CoO-gas}}}{r_b} V(\mathrm{CoO})$$

1 mark maximum

2.3.2 The equation for the standard molar Gibbs function of Co (internal layer) reads:

$$G^0_{\text{sph}}(\text{Co}, r_a, r_b) = G_{\text{bulk}}(\text{Co}) + V(\text{Co})\left(\frac{2\sigma_{\text{CoO-gas}}}{r_b} + \frac{2\sigma_{\text{CoO-Co}}}{r_a}\right) =$$
$$= G^\circ(\text{Co,s}) + V(\text{Co})\left(\frac{2\sigma_{\text{CoO-gas}}}{r_b} + \frac{2\sigma_{\text{CoO-Co}}}{r_a}\right)$$

The expression in brackets gives the additional pressure in the internal layer (see the Hint).

5 marks maximum

2.3.3 The standard Gibbs energy for reaction (1) with the double-layered nanoparticles is

$$\Delta_r G^0(1, r_a, r_b) = G^0_{sph}(\text{CoO}, r_b) + G^\circ(\text{H}_2, gas) - G^\circ(\text{H}_2\text{O,gas}) - G^0_{sph}(Co, r_a, r_b) =$$
$$= G^\circ(\text{CoO,s}) + G^\circ(\text{H}_2, gas) - G^\circ(\text{H}_2\text{O,gas}) - G^\circ(\text{Co,s}) +$$
$$+ \frac{2\sigma_{\text{CoO-gas}}}{r_b}V(\text{CoO}) - 2V(\text{Co})\left(\frac{\sigma_{\text{CoO-gas}}}{r_b} + \frac{\sigma_{\text{CoO-Co}}}{r_a}\right) =$$
$$= \Delta_r G^\circ(1) + \frac{2\sigma_{\text{CoO-gas}}}{r_b}\left(V(\text{CoO}) - V(\text{Co})\right) - \frac{2\sigma_{\text{CoO-Co}}}{r_a}V(\text{Co})$$

2 marks maximum

2.3.4 Under the assumptions made

$$\Delta_r G^\circ(1, r_a, r_b) = \Delta_r G^0(1, r_0) = \Delta_r G^\circ(1) + \frac{2\sigma_{\text{CoO-gas}}}{r_b}\left(V(\text{CoO}) - V(\text{Co})\right) - \frac{2\sigma_{\text{CoO-Co}}}{r_a}V(\text{Co}) =$$
$$= \Delta_r G^\circ(1) + \frac{2\sigma_{\text{CoO-gas}}}{r_0}\left(V(\text{CoO}) - \frac{3}{2}V(\text{Co})\right)$$

The term in brackets in the right-hand side is positive

$$\left(V(\text{CoO}) - \frac{3}{2}V(\text{Co})\right) = 6.56 \cdot 10^{-6}\ \text{m}^3$$

$\Delta_r G^0(1, r_0)$ is directly proportional to $\left(\frac{1}{r_0}\right)$. The plot (a) is correct.

3 marks maximum

2.3.5. The spontaneous forward reaction (1) is possible, when $\Delta_r G(1, r_0) \leq 0$, and

$$\Delta_r G^0(1) + \frac{2\sigma_{\text{CoO-gas}}}{r_0}\left(V(\text{CoO}) - \frac{3}{2}V(\text{Co})\right) \le RT\ln\frac{p_{\text{H}_2\text{O}}}{p_{\text{H}_2}}$$

The term in brackets in the left-hand side is positive. The left hand side of the inequality becomes more positive with the decrease of r_0. At certain point the inequality will be violated and the spontaneous oxidation will not take place.

In order to protect nanoparticles from oxidation in this case one has to shorten the radius r_0. The answer (b) is correct.

<u>2 marks maximum</u>

Problem 3. UNSTABLE CHEMICAL REACTIONS

Question	1.1	1.2	2.1	2.2	3.1	4.1	Total		**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:

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

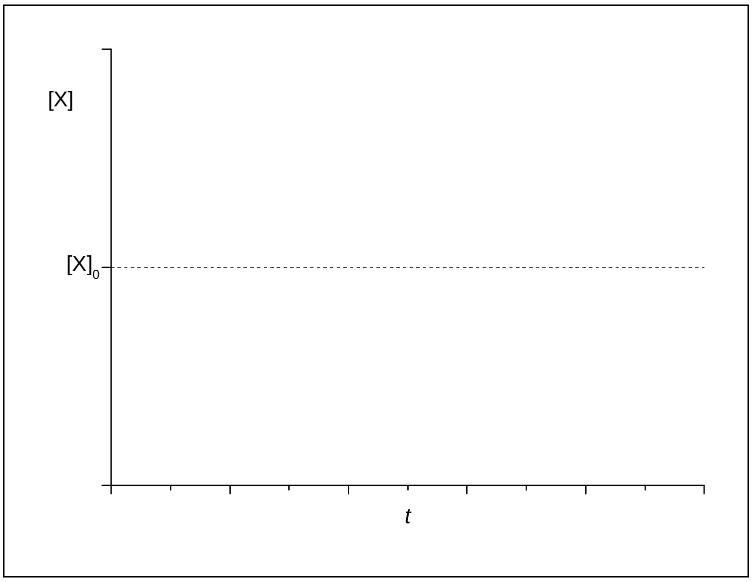
Reaction orders:

with respect to B (*i*): _______

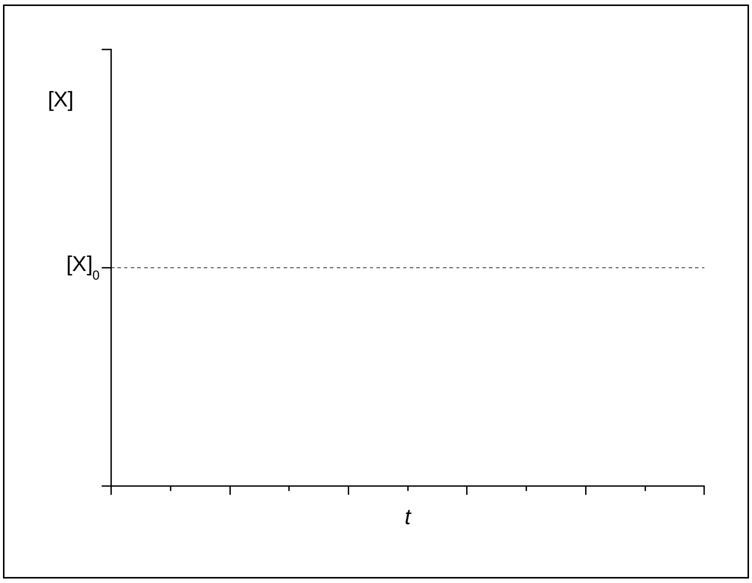
with respect to D (*ii*): _______

overall (*iii*): _______

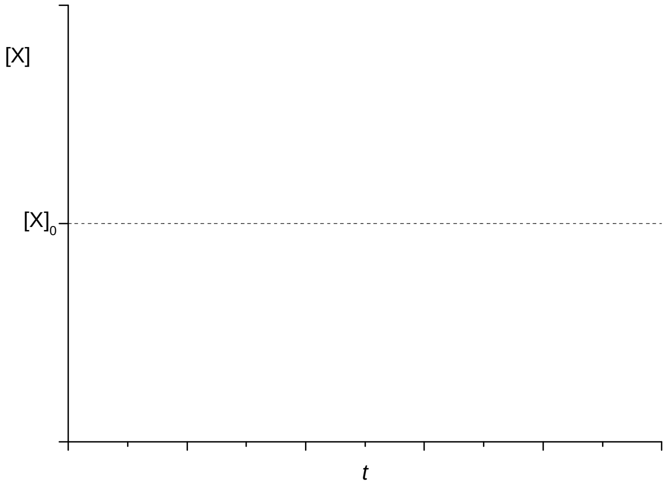
3.2.1 1) An open system, $[X]_0 > k_2/k_1$



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



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



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 =

Solution and grading scheme

3.1.1 The overall reaction equation

B + D → P 1 mark

The kinetic equation for X

$$\frac{d[\mathrm{X}]}{dt} = k_1[\mathrm{B}][\mathrm{X}]^2 - k_2[\mathrm{D}][\mathrm{X}]$$ 1 mark

<u>2 marks maximum</u>

3.1.2 Under the steady-state conditions

$$\frac{d[\mathrm{P}]}{dt} = k_2[\mathrm{D}][\mathrm{X}] = k_1[\mathrm{B}][\mathrm{X}]^2,$$

whence

$$[\mathrm{X}] = \frac{k_2[\mathrm{D}]}{k_1[\mathrm{B}]}$$

$$\frac{d[\mathrm{P}]}{dt} = \frac{k_2{}^2[\mathrm{D}]^2}{k_1[\mathrm{B}]}$$ 3 marks

The reaction order is 2 with respect to D, –1 with respect to B; the overall order is 1

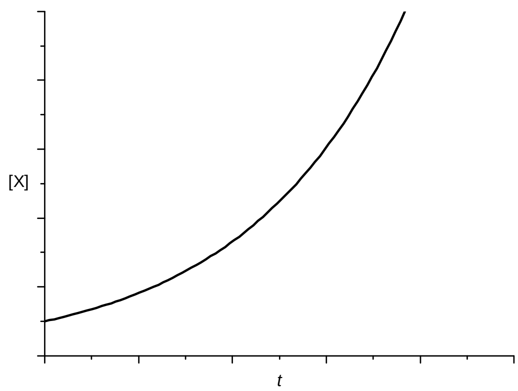
0.5 marks for each correct order

<u>4.5 marks maximum</u>

3.2.1 In an open system the initial reaction rate is:

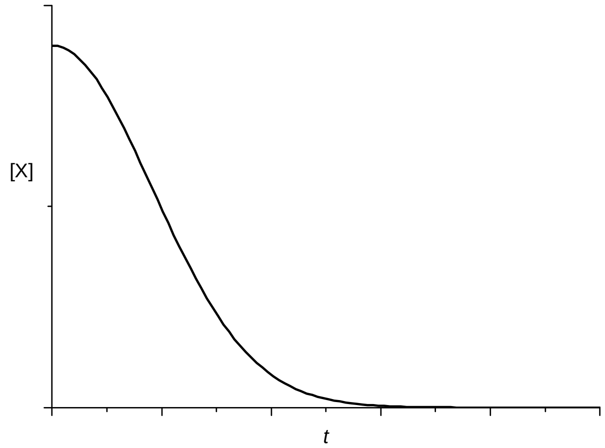
$$\frac{d[\mathrm{X}]}{dt} = [\mathrm{B}][\mathrm{X}]\left(k_1[\mathrm{X}] - k_2\right)$$

1) If $[\mathrm{X}]_0 > k_2/k_1$, then $d[\mathrm{X}]/dt > 0$ at any time, and the concentration of X monotonically increases:

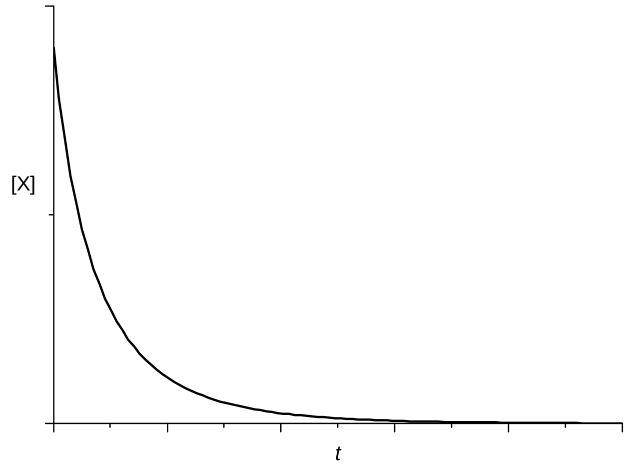


2 marks

2) If $[X]_0 < k_2/k_1$, then $d[X]/dt < 0$ at any time, and the concentration of X monotonically decreases. Two types of kinetic curves are possible. If $k_2/2k_1 < [X]_0 < k_2/k_1$, the inflection point will be observed on the kinetic curve:



But if the initial concentration is too low, $[X]_0 < k_2/2k_1$, the concentration will monotonically decrease together with its derivative.



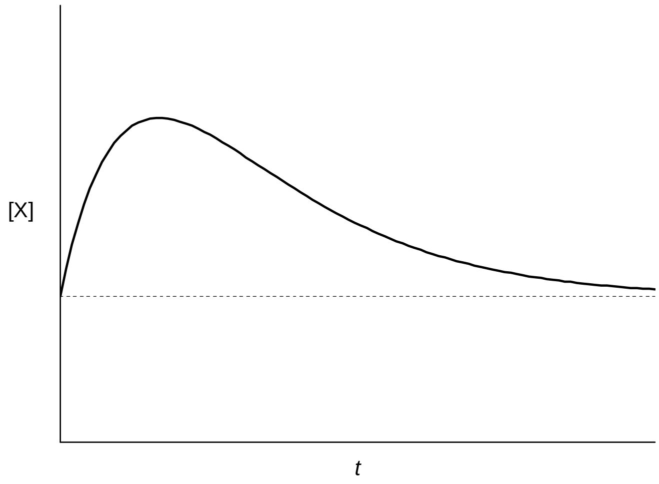
(any of these curves was accepted as a right answer) 2 marks

4 marks maximum

3.2.2 In a closed system the initial reaction rate is:

$$\left.\frac{d[\mathrm{X}]}{dt}\right|_{t=0} = k_1[\mathrm{B}]_0[\mathrm{X}]_0^2 - k_2[\mathrm{D}]_0[\mathrm{X}]_0 = [\mathrm{B}]_0[\mathrm{X}]_0\left(k_1[\mathrm{X}]_0 - k_2\right) > 0$$

Hence, at the beginning of the reaction [X] increases but it cannot increase infinitely and finally goes to its initial value, because the second reaction is irreversible:



2 marks for maximum

1 mark for the asymptotic value

3 marks maximum

3.3.1 X – $C_2H_6O_2$, Y – C_2H_4O, P – C_2H_6O. Dots denote O_2 and H_2O.

$$C_2H_6 + C_2H_6O_2 + O_2 \rightarrow 2C_2H_6O_2$$
$$C_2H_6O_2 + C_2H_4O \rightarrow 2C_2H_4O + H_2O$$
$$C_2H_6 + C_2H_4O + H_2O \rightarrow 2C_2H_6O$$

0.5 marks for each unknown substance (X, Y, P, three blanks)

3 marks maximum

3.4.1 At the highest possible temperature the rate constants are equal:

$$A_1 \exp\left(-\frac{E_{A,1}}{RT}\right) = A_2 \exp\left(-\frac{E_{A,2}}{RT}\right)$$

$$T = \frac{E_{A,2} - E_{A,1}}{R \ln \frac{A_2}{A_1}} = 354 \text{ K}$$

1 mark for the calculation

2 marks for the correct answer

3 marks maximum

Problem 4. DETERMINATION OF WATER BY FISCHER TITRATION

Question	1	2.1	2.2	2.3	3	4.1	4.2	4.3	Total		**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*

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 = ______________

Solution and grading scheme

4.1 *Equation:*

$I_2 + SO_2 + 2\ H_2O + 4\ Py = 2\ PyHI + (PyH)_2SO_4$ <u>1 mark</u>

(0.75 marks for not accounting for the formation of Py salts)

4.2.1 *T is equal to:*

$M(Na_2C_4H_4O_6 \cdot 2H_2O) = 230.05$ $2M(H_2O) = 36.04$

$m(H_2O) = 1.3520 \cdot 36.04 / 230.05 = 0.2118$ g = 211.8 mg

1 mark for the formula

$T = 211.8 / 12.20 = 17.36$ mg/mL

0.25 marks for the correct result (within 2 digits)

<u>1.25 marks maximum</u>

4.2.2 *T is equal to:*

Volume of iodine spent for 10 mL of pure CH_3OH = 2.20·10.00 / 25.00 = 0.88 mL

(0.5 marks for the correct formula of pure methanol titration)

$T = 21.537 \cdot 0.01 \cdot 10^3 / (22.70 - 0.88) = 9.87$ mg/mL

More accurately

10.00 mL of the solution contains (1000-21.5)×10.00 / 1000 = 9.785 mL of methanol

Volume of iodine spent for 9.785 mL of pure CH_3OH = 2.20·9.785 / 25.00 = 0.86 mL

$T = 21.537 \cdot 0.01 \cdot 10^3 / (22.70 - 0.86) = 9.86$ mg/mL

(1 mark for the formula of water titration, only 0.5 marks without subtracting 0.88)

$T = 9.87$ *mg/mL* 0.25 marks for the correct result

1.75 marks maximum

4.2.3 *T is equal to:*

Approach 1.

Let 1 mL of CH_3OH contain x mg H_2O, then 1 mL of **A** contains $((1.000 - 0.006) \cdot x + 5.624)$ mg H_2O.

$15.00 \cdot T = 22.45 \cdot (0.994 \cdot x + 5.624)$ – 1st titration,

$10.00 \cdot T = 25.00 \cdot x + 10.79 \cdot (0.994 \cdot x + 5.624)$ – 2nd titration.

Hence, $x = 1.13$ mg/mL, $T = 10.09$ mg/mL (10.10 without taking into account 0.994 factor)

Approach 2.

Let y mL of **B** be spent for the titration of water, contained in 1 mL of CH_3OH. Then

$$T = \frac{22.45 \cdot 5.624}{15.00 - 22.45 \cdot 0.994 \cdot y} \text{ (1st titration)} = \frac{10.79 \cdot 5.624}{10.00 - 25.00y - 10.79y} \text{ (2nd titration).}$$

Hence, $y = 0.1116$ and $T = 10.10$ mg/mL

$T = 10.09$ *mg/mL* (10.10 without taking into account 0.994 factor)

(2 marks for the correct formulas (with or without taking into account 0.994 factor) and 0.25 marks for the correct result (10.10 or 10.09))

2.25 marks maximum

4.3 *Equation(s):*

$CaO + SO_2 = CaSO_3$

$2CaO + 2I_2 = CaI_2 + Ca(OI)_2$

$6CaO + 6I_2 = 5CaI_2 + Ca(IO_3)_2$

(Instead of CaO, $Ca(OH)_2$ may be written.)

1 mark for ANY correct equation

1 mark maximum

4.4.1 *Equation(s):*

$Fe_2(SO_4)_3 + 2HI = 2FeSO_4 + \mathbf{I_2} + H_2SO_4$ 1 mark

$Fe_2(SO_4)_3 + \mathbf{H_2O} + SO_2 + CH_3OH = 2FeSO_4 + CH_3OHSO_3 + H_2SO_4$ 1 mark

(or in ionic form)

2 marks maximum

4.4.2 *Equation:*

$Fe_2(SO_4)_3 \cdot xH_2O + \mathbf{(x-1)}I_2 + xSO_2 + xCH_3OH =$

$= 2FeSO_4 + xCH_3OHSO_3 + H_2SO_4 + 2(x-1)HI$ 1 mark maximum

4.4.3. *The composition of the crystallohydrate is:*

$M(Fe_2(SO_4)_3 \cdot xH_2O) = 399.9 + 18.02x$

$m_{H2O}\text{ (g)} = \frac{0.6387 \cdot 18.02x}{(399.9 + 18.02x)}$; 1 mark

$m_{H2O}\text{ (g)} = 10.59\text{(mL)} \times 15.46\text{(mg/mL)} \times 0.001\text{(g/mg)} \times \frac{x}{x-1}$ 1 mark

$0.1637 \cdot (399.9 + 18.02x) = 11.51x - 11.51$;

$x = 8.994$

Formula: $Fe_2(SO_4)_3 \cdot 9\ H_2O$ $x = 9$ 0.25 marks (for correct answer)

2.25 marks maximum

Problem 5. A MYSTERIOUS MIXTURE (ORGANIC HIDE-AND-SEEK GAME)

Question	1.1	1.2	1.3	2.1	2.2	3.1	3.2	Total		**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% ☐

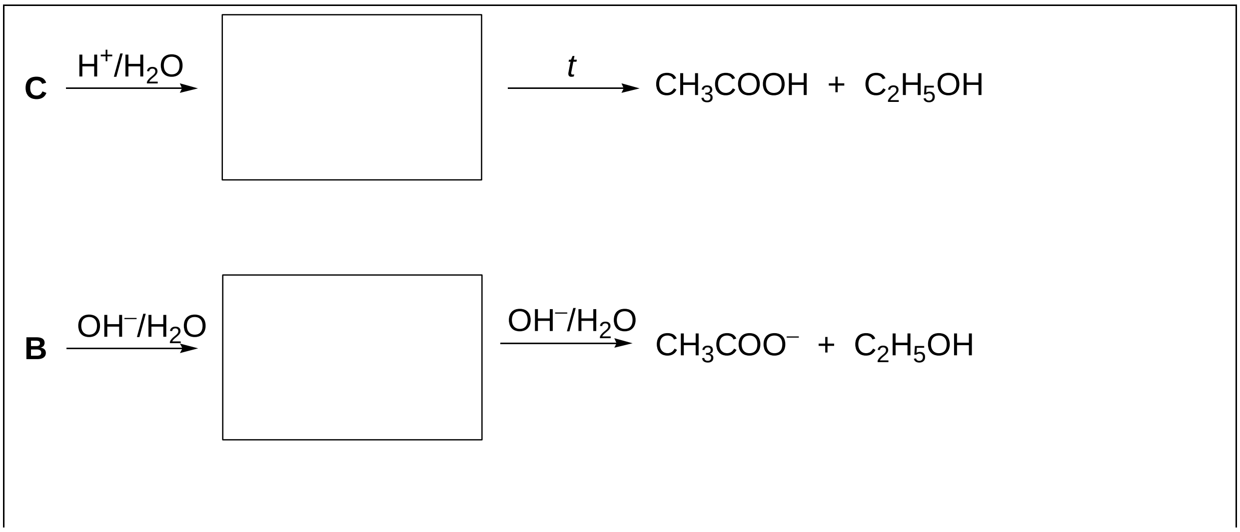
Your work:

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**.*

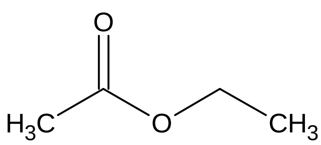


5.3.1 *The structure of senecioic acid and the reaction scheme leading to SA sodium salt from acetone.*

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

Solution and grading scheme

5.1.1 *Structure of product **D***



Ethyl acetate, ethyl ethanoate

Any structural formula or any shorter versions ($CH_3COOC_2H_5$) including the adopted shortcuts for organic radicals (Me, Et, Ac), or systematic IUPAC name – 5 marks

5.1.2 *Which class of organic compounds does **D** belong to? Check the appropriate box.*

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

The only correct answer is ester – 5 marks

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

Statement that the reaction is an equilibrium without any further actions – 1 mark

Answer to quantitative question: lower than 85% – 2 marks

Qualitative estimation of yield can be done assuming that the reaction is at equilibrium, and that the equilibrium constant is supposed to not vary with temperature and composition of the reaction mixtures.

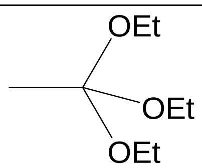
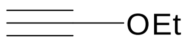
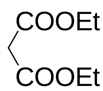
$$K = \frac{[AcOEt][H_2O]}{[AcOH][EtOH]} = \frac{(0.85)^2}{0.15 \cdot 1.15} = 4.2$$

Calculation of yield using this constant in 1:1 mixture gives 67%

yield = 67%

maximum – 10 marks, if the yield is computed within 67±1% error limits

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

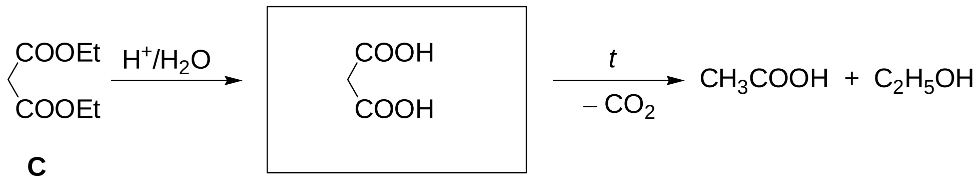
 $CH_3C(OEt)_3$ triethyl orthoacetate, 1,1,1-triethoxyethane	 HC≡COEt ethoxyacetylene, ethynylethyl ether	 $CH_2(COOEt)_2$ diethyl malonate
A	***B***	***C***

Each structure represented by structural formula or unambiguous linear notation – 10 marks. Systematic name given in place of structure – 5 marks

30 marks maximum

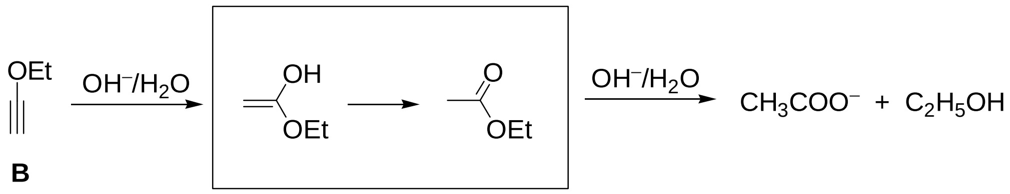
5.2.2 *Draw in the boxes intermediate compounds formed during the acidic hydrolysis of **C**, and basic hydrolysis of **B**.*

a) Malonic acid is formed as intermediate in the hydrolysis of diethyl malonate – 5 marks



Also accepted will be monoethyl malonate – 2 marks. Maximum 5 marks

b) Hydrolysis of ethoxyacetylene starts from the addition of hydroxide to the triple bond to give unstable enolic form of ethylacetate, into which it immediately is transformed



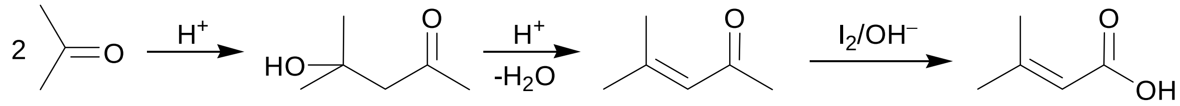
Indication of any of keto- or enol forms of ethylacetate – 5 marks

Hydrolysis of strong ether bond to give hydroxyacetylene, or any forms coming along this path (ketene, diketene) is impossible and is not allowed – 0 marks

<u>Maximum for a) and b) together – 10 marks</u>

5.3.1 *The structure of senecioic acid*

From acetone alone the synthesis includes aldol condensation, dehydration, with subsequent iodoform reaction 3 marks



Senecioic acid structure alone – 4 marks, with scheme – <u>maximum 10 marks</u>

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

Iodoform, triiodomethane, CHI_3 – <u>5 marks</u>

Problem 6. SILICATES AS THE BASE OF THE EARTH CRUST

Question	1.1	1.2	2.1	2.2	2.3	2.4	3.1	3.2	Total		**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 *The fragment 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 meta-silicate (LGL)*

Solution and grading scheme

6.1.1

$SiO_3^{2-} + 2CO_2 + 2H_2O$ = "H_2SiO_3"↓ (Silica acid gel) $+2HCO_3^-$

or

$SiO_2(OH)_2^{2-} + 2CO_2 + H_2O$ = "H_2SiO_3"↓ $+ 2HCO_3^-$

or

$SiO_3^{2-} + CO_2 + H_2O$ = "H_2SiO_3"↓ $+ CO_3^{2-}$

<u>3 marks maximum</u>

2 marks if silicic acid is written in any form

1 mark if the reaction contains carbonate (or bicarbonate) ions with silicic acid missing

6.1.2

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

$SiO_4^{4-} + H_2O = [SiO_3(OH)]^{3-} + OH^-$ or

$SiO_4^{4-} + H^+ = [SiO_3(OH)]^{3-}$ or

$[SiO_2(OH)_2]^{2-} + H^+ = [SiO(OH)_3]^-$ Yes ☒ No ☐

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

$SiO_4^{4-} + 2H_2O = [SiO_4(H_2O)_2]^{4-}$

Yes ☐ No ☒

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

$2\ SiO_4^{4-} + H_2O = [O_3Si\text{-}O\text{-}SiO_3]^{6-} + 2\ OH^-$ or

$2\ SiO_4^{4-} + 2H^+ = [O_3Si\text{-}O\text{-}SiO_3]^{6-} + H_2O$ or

$2SiO_2(OH)_2^{2-} + H_2O = [O\text{-}Si(OH)_2\text{-}O\text{-}Si(OH)_2\text{-}O]^{2-} + 2\ OH^-$ Yes ☒ No ☐

<u>9 marks maximum</u>

2 marks for each correct reaction

1 mark for each correct choice of check-boxes

6.2.1 n = 6 (assuming oxidation numbers of silicon (+4) and oxygen (–2), or taking into account its structure and the charge of orthosilicate ion (–4))

2 marks maximum

1 mark penalty for miscalculation

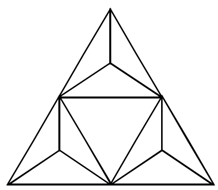
6.2.2

$Si_3O_9 \equiv 3\,[SiO_4] - 3\,O$, i.e. there are 3 oxygen atoms bridging adjacent tetrahedra

2 points maximum

1 point penalty for miscalculation

6.2.3

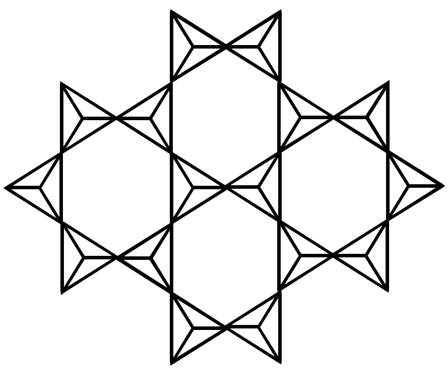


3 marks maximum

6.2.4 Calculations:

m = 4 (assuming oxidation numbers of silicon (+4) and oxygen (–2), or taking into account its structure and the charge of orthosilicate ion (–4))

$Si_4O_{10} \equiv 4[SiO_4] - 6O$, i.e. the formula of the tetrahedron is now $SiO_{2.5}$, which is possible if 1 O atom belongs to this tetrahedron and the other three are shared between 2 tetrahedra (their contribution = 3/2). This is possible if the tetrahedra are set on a plane and joined together through all apexes of their bases.



10 marks maximum

2 marks for charge determination

3 marks for determination of the number of oxygen bridges

5 marks for the correct structure

1 mark penalty if 6 to 15 tetrahedra shown, the connection being correct

3 marks penalty if less than 6 tetrahedra shown (i.e. it is not clear that polyhedra form layer)

4 marks penalty for connection via apexes, but in 3D network

4 marks penalty for connection via apexes, but in 1D chain

0 mark of 5 for any other structure

6.3.1 pH = 4

$$Cu(H_2O)_4^{2+} + H_2O = Cu(OH)(H_2O)_3^{+} + H_3O^{+},$$

$$[H^+] \approx (c\, K_a^{I})^{1/2} = 1 \cdot 10^{-4}\ M,\ pH = -\log[H^+] = 4$$

<u>5 marks maximum</u>

1 mark penalty for miscalculation

2 marks penalty for wrong expression of $[H^+]$ via K_a^{I}

2 marks penalty if there are some errors in definition of pH (e.g. using ln instead of log)

3 marks penalty if the hydrolysis reaction is wrong

6.3.2

$$CuSO_4 + Na_2SiO_3 + 2H_2O = Cu(OH)_2\downarrow + \text{“}H_2SiO_3\text{”}\downarrow + Na_2SO_4$$

or

$$2CuSO_4 + Na_2SiO_3 + 2H_2O = (CuOH)_2SO_4\downarrow + \text{“}H_2SiO_3\text{”}\downarrow + Na_2SO_4$$

This (or those) reaction(s) (apart from formation of copper silicate) can be deduced from the fact that the reaction describes mutual (self-amplifying) hydrolysis. It comes from the previous parts of the task: pH of LGL is greater than 7 (see questions **6.2**), and pH of copper sulfate solution is less than 7 (see **6.3.1**).

<u>3 marks maximum</u>

2 marks if reaction coefficients are wrong

1 mark if only one of two principal precipitates shown ($Cu(OH)_2\downarrow$ or “H_2SiO_3”$\downarrow$)

Problem 7. ATHEROSCLEROSIS AND INTERMEDIATES OF CHOLESTEROL BIOSYNTHESIS

Question	1.1	1.2	2.1	2.2	2.3	2.4	2.5	Total		**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:_______________

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

Solution and grading scheme

7.1.1 E2-**E4** catalyze one and the same (and only one) reaction type. The only reaction which can be carried out three times in a row is monophosphorylation (all the rest reaction types are not consistent with either initial or final products). This is also supported by presence of pyrophosphate residue in IPP and liberation of inorganic products (including inorganic phosphate) upon spontaneous decomposition of **X1**.

X is a monocarboxylic acid composed of atoms of three elements: carbon, hydrogen and oxygen. It can contain neither sulfur which is found in CoA nor phosphorus which is introduced into intermediates on the pathway from HMG-CoA towards IPP or present in CoA. Thus, **E1** catalyzes non-hydrolytic removal of CoA from HMG-CoA and is not involved in phosphorylation. Since water is not a substrate in this reaction, liberation of CoA must be conjugated with another reaction which affects the carboxylic group esterified in HMG-CoA. The only possible variant is its 4 electron reduction towards hydroxyl group. **E1** can not catalyze dehydration because of optical activity of **X** (removal of water leads to the loss of sole chiral center). Decarboxylation is excluded, since **X**, being an acid, must contain a carboxylic group. Oxidation of tertiary hydroxyl group in HMG-CoA according to β-oxidation mechanism is impossible. Further evidence comes from the fact that the carboxylic group initially involved in thioester bond formation is present as the residue of hydroxyl group in IPP. So:

E1 ***4, 5***

E3 ***6***

12 marks maximum

E1: 9 marks if 2 variants are given and both are correct.

4 marks if only one variant is given and it is correct

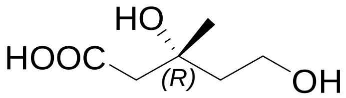
4 marks if two correct and one incorrect variants are given

0 mark if one correct and any number of incorrect variants are given

0 mark if more than three variants are given.

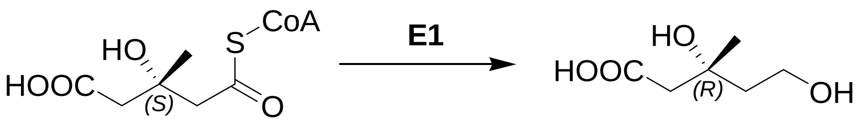
E3: 3 marks if only correct variant is given. Otherwise 0 mark

7.1.2 Based on the reaction types catalyzed by **E1** and configuration of HMG-CoA stereocenter, the structure of **X** is:



X, mevalonic acid

Note the absolute configuration of the chiral center is changed as a result of HMG-CoA metabolism into mevalonic acid due to alteration of substituents priority.



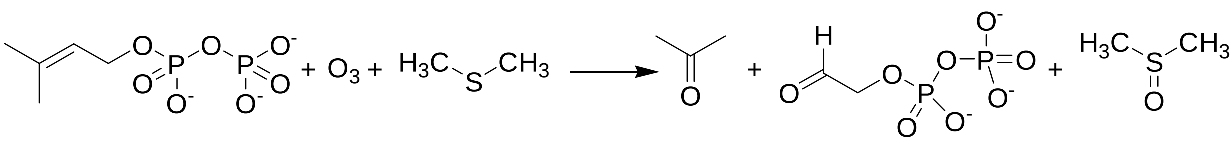
<u>12 marks maximum</u>

8 marks for correct structural formula

4 marks for correct stereochemistry (only in case both the structure is correct and R-isomer is indicated; otherwise 0 mark).

No penalty for incorrect stereochemistry or absence of stereochemical information

7.2.1 Reaction equation for reductive ozonolysis



<u>5 marks maximum</u>

4.5 marks for correct products (1.5 marks each), incorrect structures not penalized

0.5 mark for correct equation coefficients

7.2.2 DAP molecule contains only one carbon atom which can be involved in the formation of C–C bond during **Y** biosynthesis. Irrespective of the way this molecule is incorporated in **Y**, ozonolysis of this fragment will lead to dimethyl ketone (acetone). (See DAP ozonolysis reaction in **7.2.1**). Thus, acetone can be unambiguously attributed to **Y1**, since it contains 3 carbon atoms (**Y2** and **Y3** contain 5 and 4 carbon atoms, respectively). Taking into account the ratio between ozonolysis products, we have:

$$n_Y(C)= 2 \cdot n_{Y1}(C) + 4 \cdot n_{Y2}(C) + n_{Y3}(C) = 2 \cdot 3 + 4 \cdot 5 + 4 = 30$$

Y is an acyclic molecule, thus DAP residues can be found only at its ends. **Y** has only two ends, since IPP contains only two elongation sites (at least three such sites are needed to get a branched molecule). Since reductive ozonolysis of one **Y** molecule produces two acetone molecules, **Y** contains 30 carbon atoms.

To determine the number of hydrogen atoms double bonds in **Y** should be counted. Formation of each double bond reduces by 2 the number of hydrogen atoms in the coupling product as compared to the sum of atoms of starting substances. The ratio of **Y** to the sum of its ozonolysis products is 1:7 (2+4+1), which corresponds to 6 double bonds in **Y.** Then, by using the general formula for alkanes we have:

$$n(H) = 2 \cdot n_Y(C) + 2 - 2 \cdot n_{c=c} = 30 \cdot 2 + 2 - 6 \cdot 2 = 50$$

Y (squalene) formula – $C_{30}H_{50}$.

Number of carbon atoms <u>30</u>

Number of hydrogen atoms <u>50</u>

Gross formula of **Y** – $C_{30}H_{50}$

<u>12 marks maximum</u>

8 marks for correct justification of molecular formula

4 marks for correct molecular formula

7.2.3 IPP and DAP are structural isomers containing 5 carbon atoms each. Since all carbon atoms of these substances are found in **Y**, one can calculate the total quantity of IPP and DAP molecules needed to synthesize **Y**:

$$n(IPP\&DAP) = n_Y(C) / 5 = 30 / 5 = 6$$

The number of DAP molecules was determined earlier and is equal to 2. Then, 4 molecules of IPP are needed.

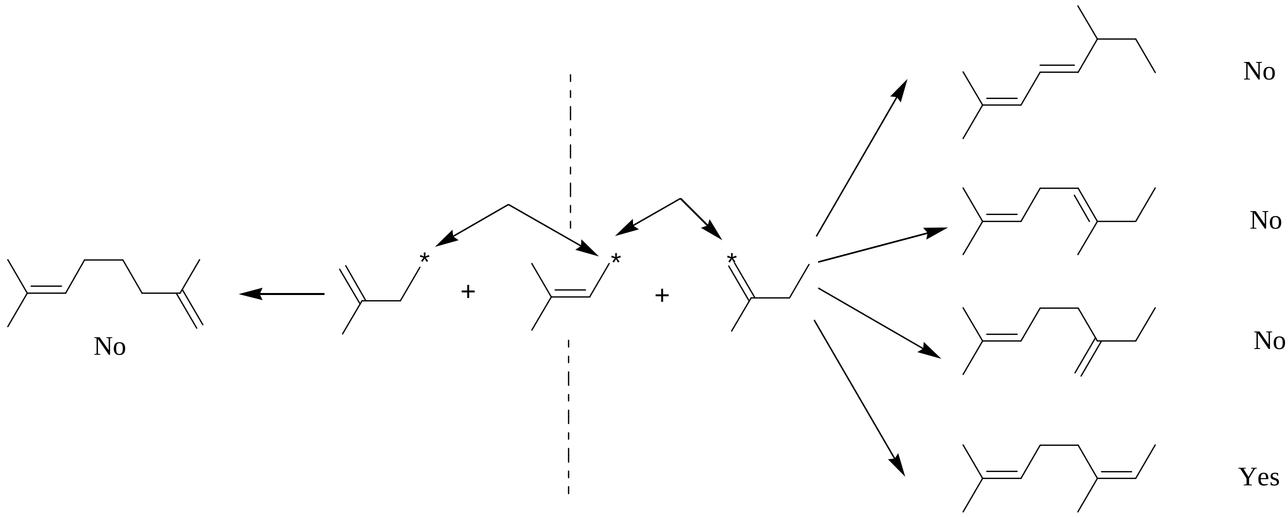
Number of DAP molecules <u>2</u> Number of IPP molecules <u>4</u>

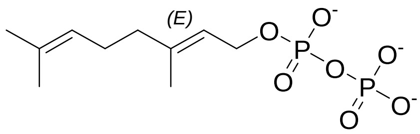
<u>7 marks maximum</u>

3.5 marks for calculation of the total number of DAP and IPP molecules

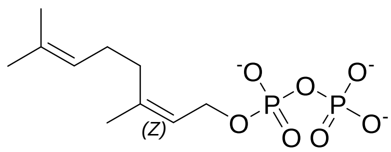
3.5 marks for correct individual numbers of DAP and IPP molecules

7.2.4 All possible combinations that do not alter hydrocarbon skeleton are given below (pyrophosphate fragments not shown). Two groups of products differing in carbon atoms involved in coupling reaction are separated by the dashed line. IPP fragments should be attached to DAP so that ozonolysis of the product leads to **Y2** containing 5 carbon atoms. Only one variant is possible if stereochemistry is not taken into consideration and two variants with stereochemical details





or



The upper isomer is geranyl pyrophosphate

<u>8.5 marks maximum</u>

8.5 marks for correct structure

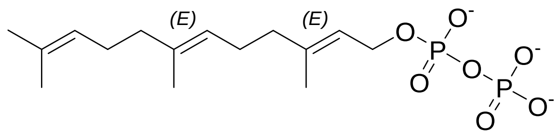
No penalty for stereochemistry, any correct structure is accepted

2.5 marks if ozonolysis of the product leads to acetone, but does not lead to the compound with 5 carbon atoms

2.5 marks if ozonolysis of the product leads to the compound with 5 carbon atoms, but does not lead to acetone

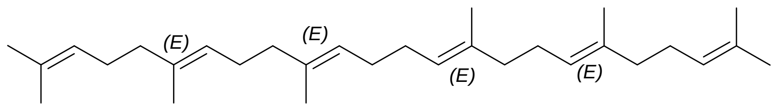
0 mark for any other variant

7.2.5 It is seen from the coupling reaction (Scheme 2) that **Y4** contains 15 carbon atoms or 1 DAP and 2 IPP fragments, the latter being attached to the former consecutively. It is important to note that **Y3** can not be found in two hydrocarbon residues originating for **Y4,** since **Y3** is formed as a result of ozonolysis in a molar ratio of 1:1 to **Y**. Thus, geranyl phosphate is the intermediate on the way to **Y** (all double bonds in *trans* configuration). Attachment of the next IPP fragment to geranyl phosphate leads to the product giving 1 molecule of **Y1** and 2 molecules of **Y2** upon its ozonolysis. Thus, **Y4** structure with stereochemical details:



Y4, farnesyl pyrophosphate

Combining two hydrocarbon fragments of **Y4** and taking into account that the double bond between them is being reduced we get the following structure of **Y**:



Y, squalene

16 marks maximum

9 marks for farnesyl pyrophosphate (6.5 marks for correct structural formula and 2.5 marks for correct stereochemistry)

7 marks for squalene (5 marks for correct structural formula and 2 marks for correct stereochemistry)

2.5 marks penalty for unreduced double bond in squalene

Problem 8. ATRP ALLOWS NEW POLYMERS

Question	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	Total		**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* =**

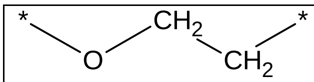
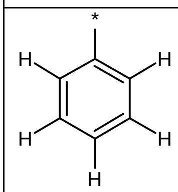
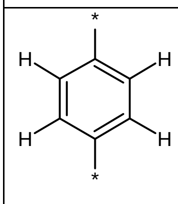
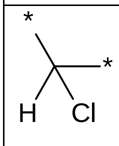
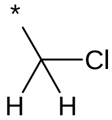
8.2.2 *Degree of polymerization of the obtained polymer.*

Your justification:

DP =

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

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:

Solution and grading scheme

8.1.1 *Expressions for the rates of ATRP elementary stages: activation (v_{act}), deactivation (v_{deact}), propagation (v_p) and termination (v_t)*

$v_{act} = k_{act}\cdot[\text{R-Hal}]\cdot[\text{CuHal(Ligand)}_k]$ 2 marks

$v_{deact} = k_{deact}\cdot[\text{R}^{\cdot}]\cdot[\text{CuHal}_2\text{(Ligand)}_k]$ 2 marks

$v_p = k_p\cdot[\text{R}^{\cdot}]\cdot[\text{M}]$ 2 marks

$v_t = 2k_t\cdot[\text{R}^{\cdot}]^2$ 2 marks (no penalty for missing 2)

<u>8 marks maximum</u>

8.1.2 *Comparison of rates of ATRP elementary stages*

Since all the chains grow with equal rate, the process proceeds as living polymerization. Living radical polymerization is possible only if concentration of active radicals is low to prevent chain transfer and termination. So:

$v_{deact} >> v_{act}$ 3 marks

The portion of active radicals must be small, so the equilibrium is shifted towards dormant species.

$v_{deact} >> v_p$ 3 marks

Propagation rate should be much slower than that of deactivation to make chains propagate with equal rate.

$v_{deact} >> v_t$ 3 marks

Termination does not occur since the total number of polymer chains is equal to a certain constant number – number of initiator molecules.

9 marks maximum

8.2.1 *Calculation of mass (m) of the obtained polymer.*

1st variant

$[M] = [M]_0 \exp(-k_P[R\cdot]t)$ or $n(\text{MMA}) = n_0(\text{MMA})\exp(-k_P[R\cdot]t)$ 1 mark

Quantity of MMA monomer remaining after polymerization during 1400 s is

$31.0 \cdot \exp(-1616 \cdot 1.76 \cdot 10^{-7} \cdot 1400) = 20.8$ mmol. 2 marks

Quantity of monomer consumed during polymerization:

31 – 20.8=10.2 mmol 1 mark

Mass of the obtained polymer is

$m = \Delta n(\text{MMA}) \cdot M(\text{MMA}) = (10.2/1000) \cdot 100.1 = 1.03$ g 1 mark

2nd variant

$[M] = [M]_0 \exp(-k_P[R\cdot]t)$ or $n(\text{MMA}) = n_0(\text{MMA})\exp(-k_P[R\cdot]t)$ 1 mark

Quantity of MMA monomer consumed during 1400 seconds of polymerization is

$\Delta n(\text{MMA}) = n_0(\text{MMA})(1 - \exp(-k_p \cdot [R^\bullet] \cdot t)) = 31.0 \cdot (1 - 1616 \cdot 1.76 \cdot 10^{-7} \cdot 1400) = 10.2$ mmol

3 marks

Mass of the obtained polymer is

$m = \Delta n(\text{MMA}) \cdot M(\text{MMA}) = (10.2/1000) \cdot 100.1 = 1.03$ g 1 mark

3rd variant

$$\ln\left(\frac{[M]}{[M]_0}\right) = -k_P[R\cdot]t = -1616 \cdot 1.76 \cdot 10^{-7} \cdot 1400 = -0.398$$ 1 mark

$$\frac{[M]}{[M]_0} = e^{-0.398} = 0.672$$ 1 mark

$$\frac{[M]}{[M]_0} = \frac{n(\text{MMA})}{n_0(\text{MMA})}$$

$n(\text{MMA}) = 0.672 \cdot n_0(\text{MMA}) = 20.8$ mmol 1 mark

Quantity of monomer consumed during polymerization is 31 – 20.8 = 10.2 mmol

1 mark

Mass of the obtained polymer is

$$m = \Delta n(\text{MMA}) \cdot M(\text{MMA}) = (10.2/1000) \cdot 100.1 = 1.03\,\text{g}$$ 1 mark

***m* = 1.03 g** 5 marks maximum

8.2.2 *Calculation of degree of polymerization (DP) of the obtained polymer.*

The number of growing chains is equal to the number of TsCl molecules (0.12 mmol)

2 marks

At the first stage, 7.3 mmol of MMA was consumed (0.73/100.1).

The total quantity of monomers at the beginning of the 2nd stage is

23.7 + 23.7 = 47.4 mmol. 2 marks

Since the monomers have the same reactivity, they will be involved in polymerization with the same rate.

Quantity of monomers consumed during the second stage is

$$\Delta n = n_0(1 - \exp(-k_P[R\cdot]t)) = 47.4(1 - \exp(-1616 \cdot 1.76 \cdot 10^{-7} \cdot 1295)) = 14.6 \text{ mmol.}$$

4 marks

Totally 7.3+14.6 = 21.9 mmol of monomers was polymerized during two stages.

2 marks

DP = 21.9/0.12 = 182.5 1 mark

DP = 182-183 (all answers within this range are credited) 11 marks maximum

8.2.3 *Structure of the obtained polymer.*

The product of polymerization is a block copolymer because it was obtained by sequential polymerization on living chains.

The first block is built of MMA units solely. The DP is 7.3/0.12 = 60.8 ≈ 61 monomer units.

The second block is obtained by copolymerization of two competing monomers with the same reactivity. So, it is a statistical copolymer. Fractions of A and B in the 2nd block are equal because their concentrations in the reaction mixture at the beginning of the 2nd stage were equal. The DP of the 2nd block is 183-61 = 122 monomer units (121 is also correct if the total DP in **8.2.2** is 182).

Ts-A_{61}-block-(A-stat-B)$_{61}$-Cl or Ts-A_{61}-block-(A_{61}-stat-B_{61})-Cl

14 marks maximum

4 marks for block copolymer with blocks A and co-AB

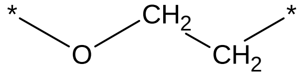
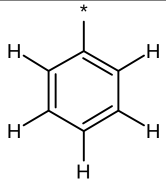
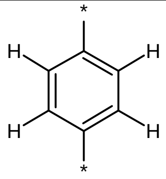
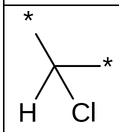
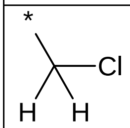
4 marks for an indication of the statistic character of the 2nd block

1 mark for equal fractions of A and B in the 2nd block

2 marks for correct DPs of each block

1 mark for indication of terminal groups

8.3.1 *Assignment of NMR signals to substructures given in the Answer Sheet.*

	a, b, g 3x1.5 marks
	c 2 marks
	d 2 marks
	e 4 marks
	f 4 marks

<u>16.5 marks maximum</u>

8.3.2 *Determination of molar fractions of units C and D and molecular weights of P1 and P2.*

Intensity of multiplets b and g is 40.2, so intensity per 1 proton is 40.2 / 4 / 58 = 0.173 for both copolymer spectra 2 marks

Intensity of multiplet c is 13.0, which is equivalent to 13.0 / 0.173 = 75 protons. Taking into account that each styrene ring has 5 aromatic protons, DP of styrene block is 75/5 = **15.** 2 marks

Molar fraction of styrene units in P1 is 15 / (15+58) = **20.5%** 1 mark

Intensity of multiplet d is 10.4, which is equivalent to 10.4/0.173=60 protons. Since each monomer unit of *p*-chloromethylstyrene has 4 protons, DP of PCS is 60/4=15. 2 marks

Molar fraction of D is 15/(15+58) = **20.5%** 1 mark

M(P1) = 15.03 + 58·44.05 + 72.06 + 15·104.15 + 35.45 = **4240** 2 marks

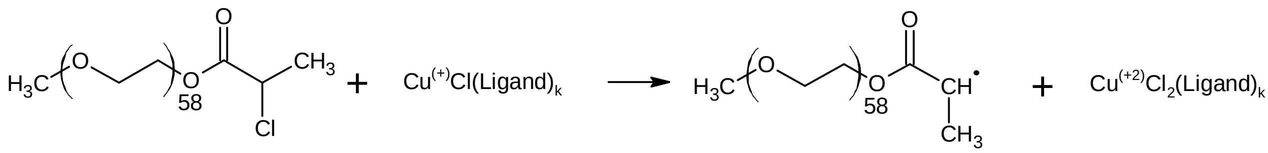
M(P2) = 15.03 + 58·44.05 + 72.06 + 15·152.62 + 35.45 = **4967** 2 marks

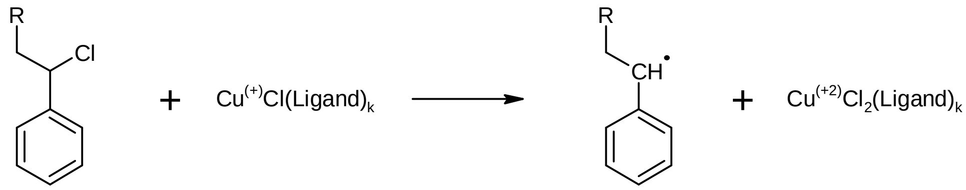
<u>12 marks maximum</u>

8.3.3 *All possible reactions of activation occurring during the synthesis of P1 and P2.*

<u>10 marks maximum</u>

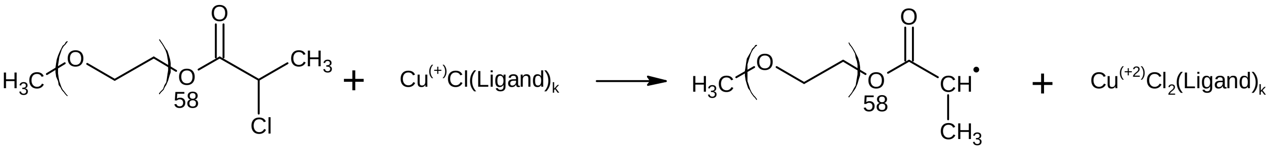
P1: (1.5+2) marks

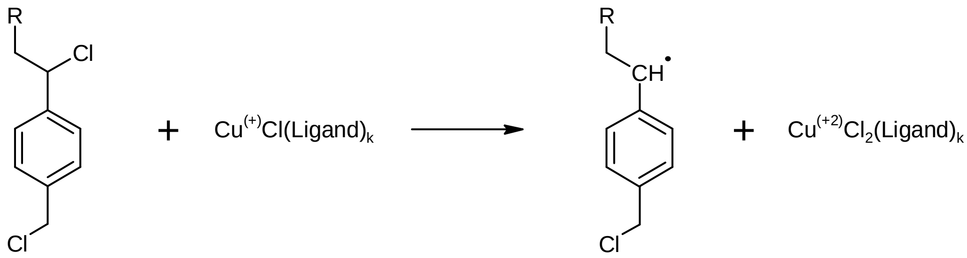


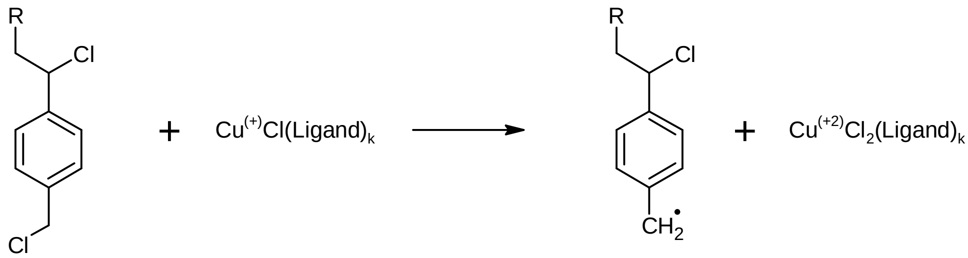


Here R is used for the macroinitiator fragment with one or several styrene units attached.

P2: (1.5+2+3) marks







Here R is used for the macroinitiator fragment with one or several p-chloromethylstyrene units attached.

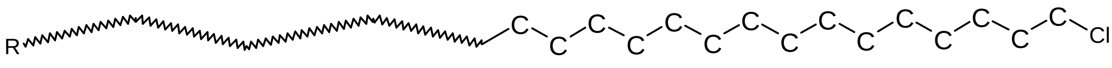
8.3.4 *The structure of P1 and one of possible structures of P2*

P1 is a block copolymer of PEO and PS. The PS block contains 15 units.

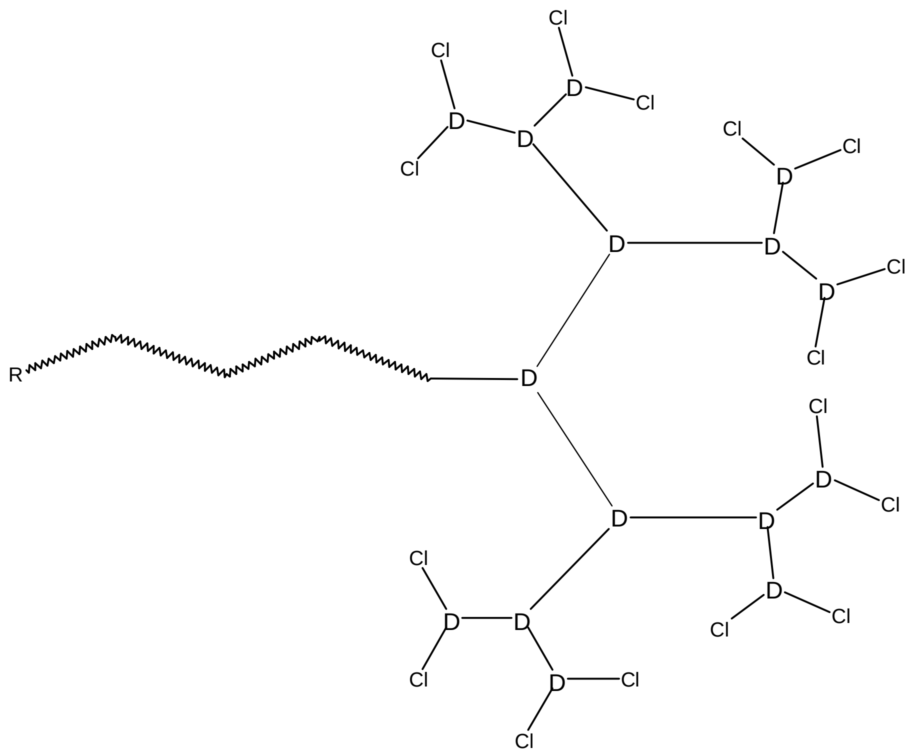
P2 is a block copolymer composed of PEO block and branched styrene block.

The integral intensity of multiplet f is 2.75, so 2.75 / 0.173 = 15.9, that is about 16 protons or 8 chloromethyl groups.

d) If there is no branching in molecule P2, it would contain 15 chloromethyl groups. Each branching reduces the number of such groups by 1. Thus P2 has 15 – 8 = 7 branchings. Every structure with 7 branchings is correct if each monomer unit is linked with not more than 3 other monomer units

P1 

P2



<u>13.5 marks maximum</u>

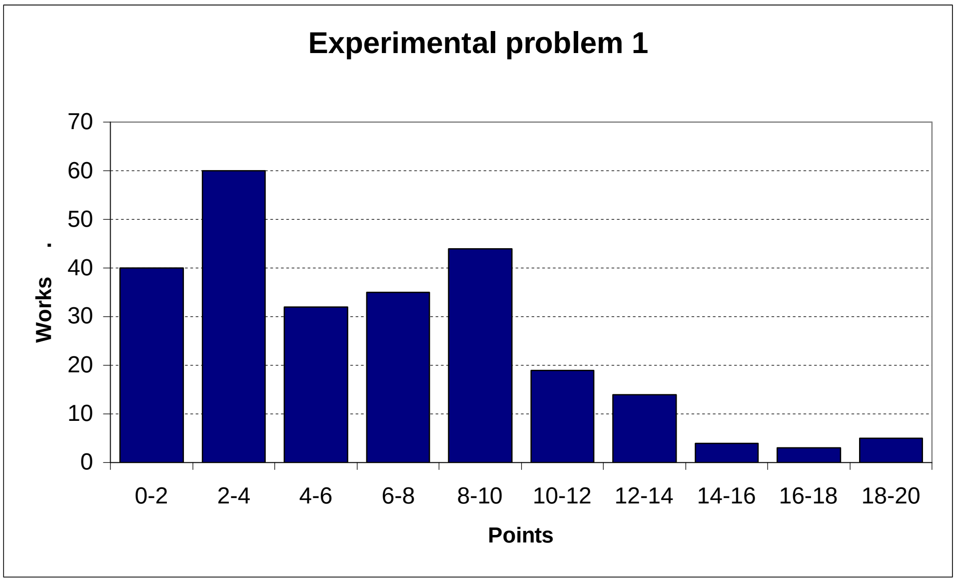
2 marks for P1

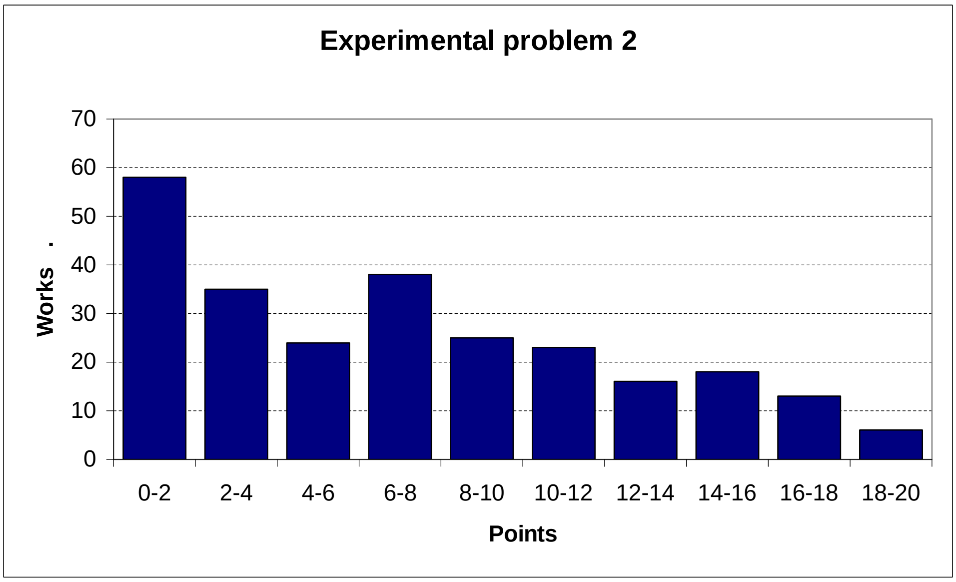
7.5 marks for completely correct structure of P2

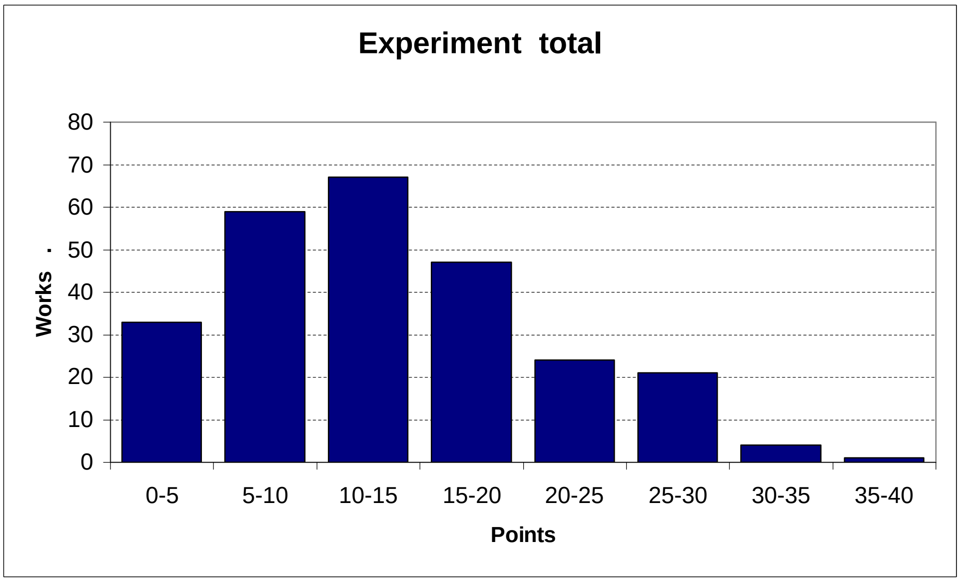
4 marks for structure of P2 with nonzero but incorrect number of branchings

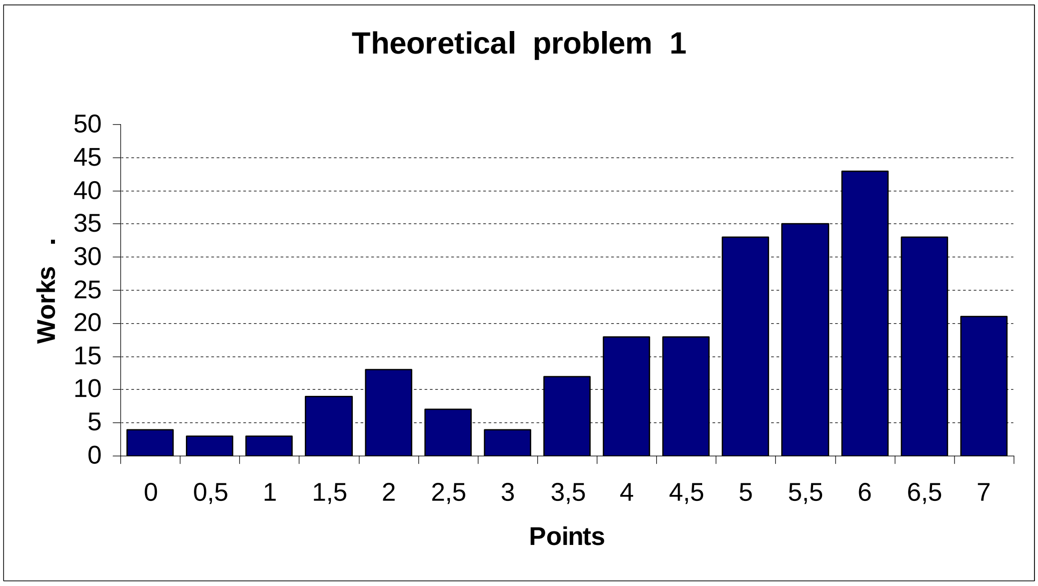
4 marks penalty if there is a unit linked with more than 3 other monomer units

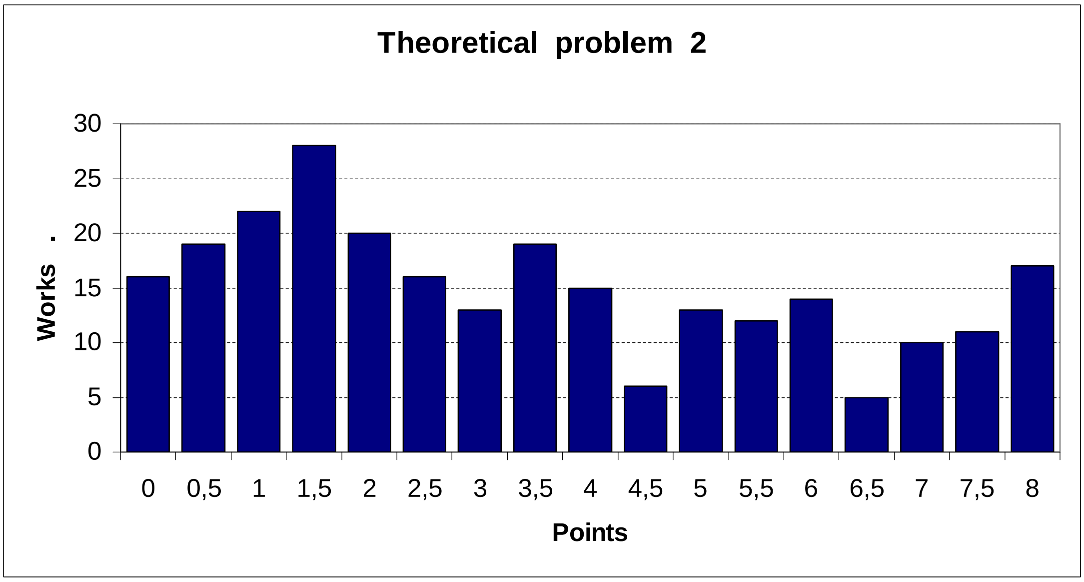
STATISTICAL ANALYSIS OF THE PROBLEMS

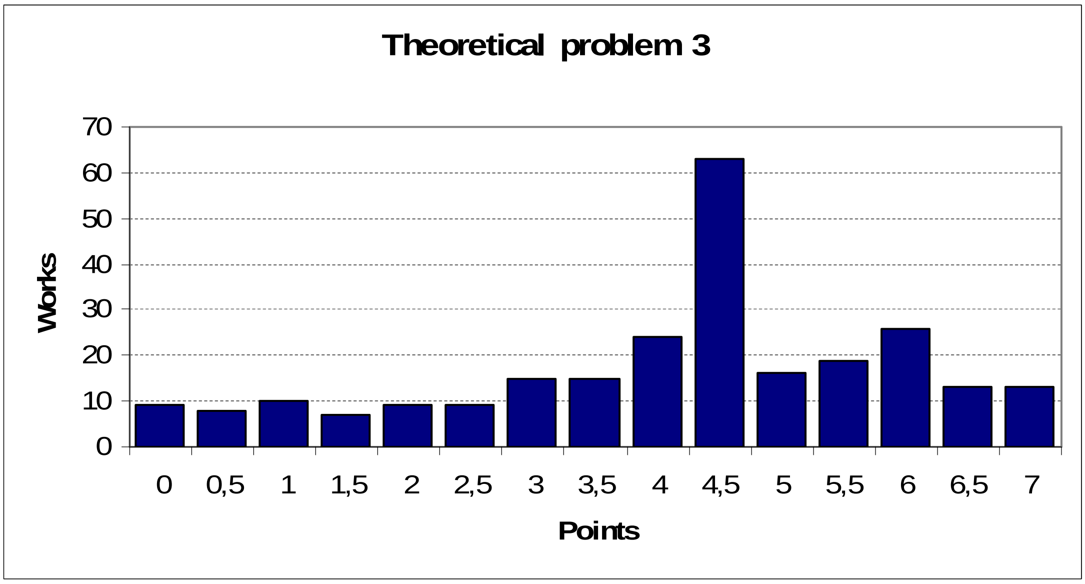


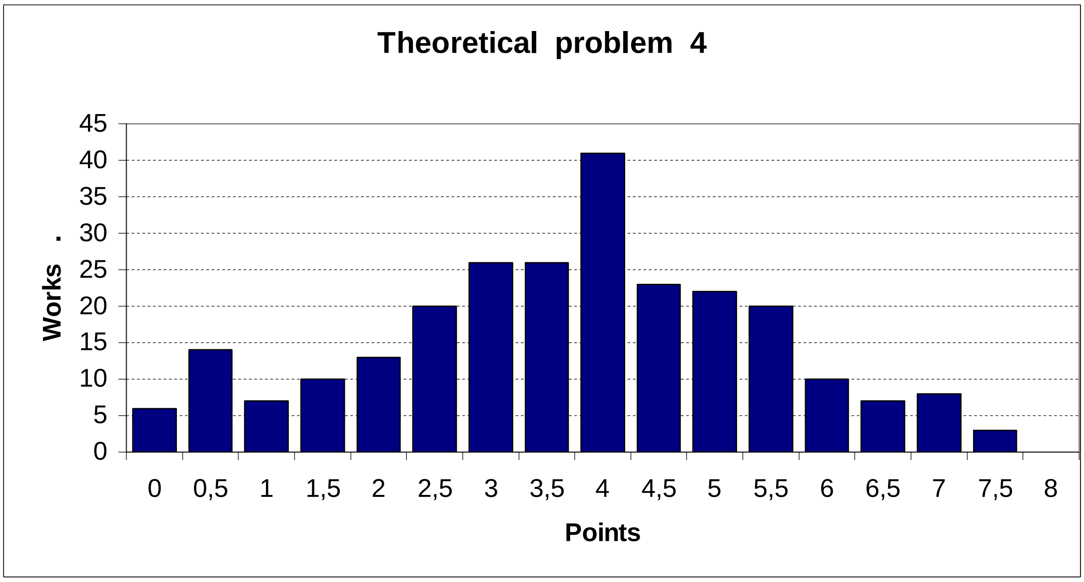


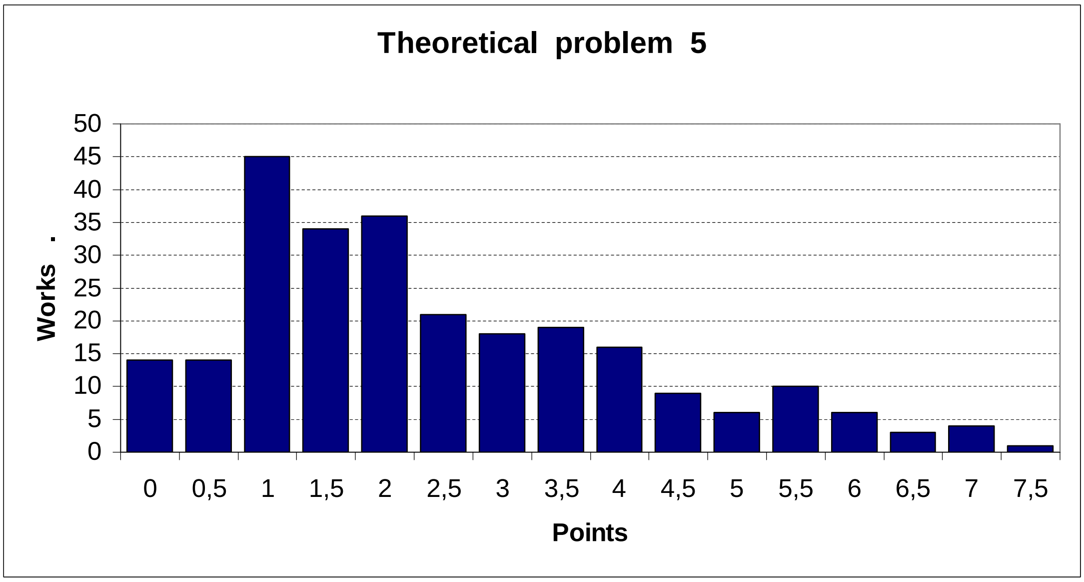


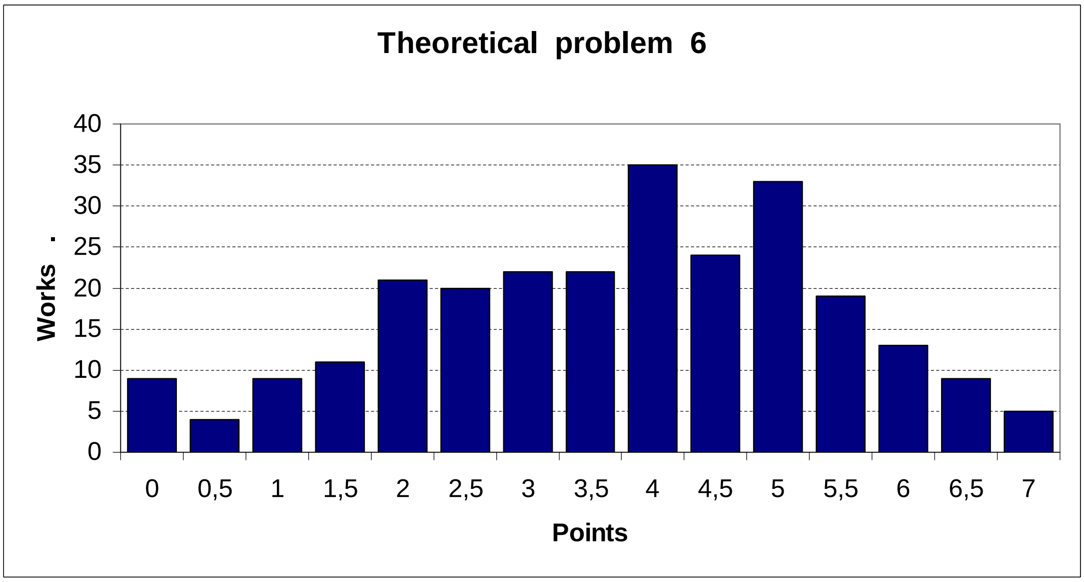

Theoretical problem 1
Works
50
45
40
35
30
25
20
15
10
5
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7
Points

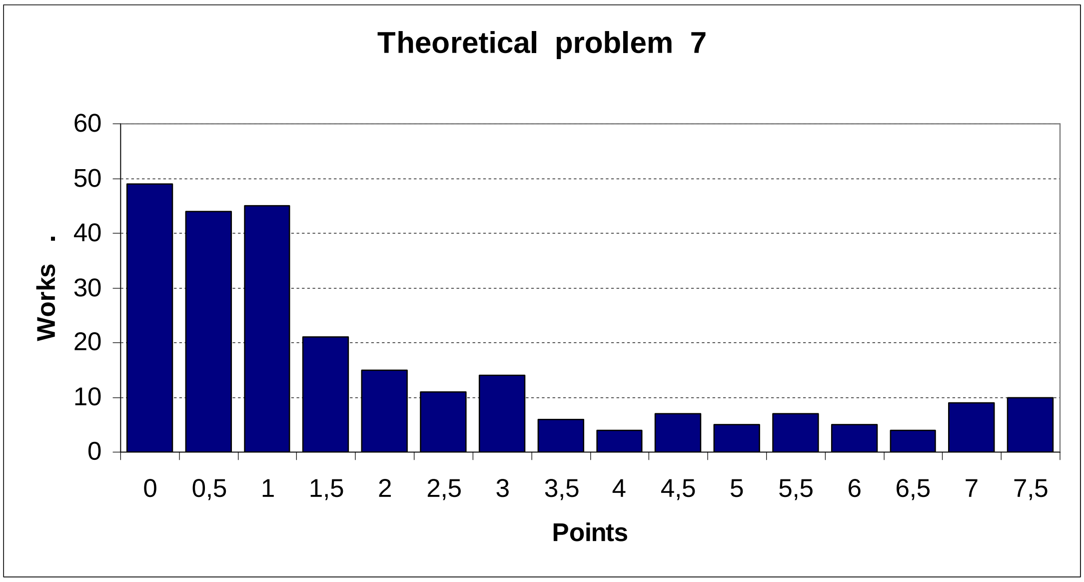

Theoretical problem 2
Works
30
25
20
15
10
5
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5 8
Points

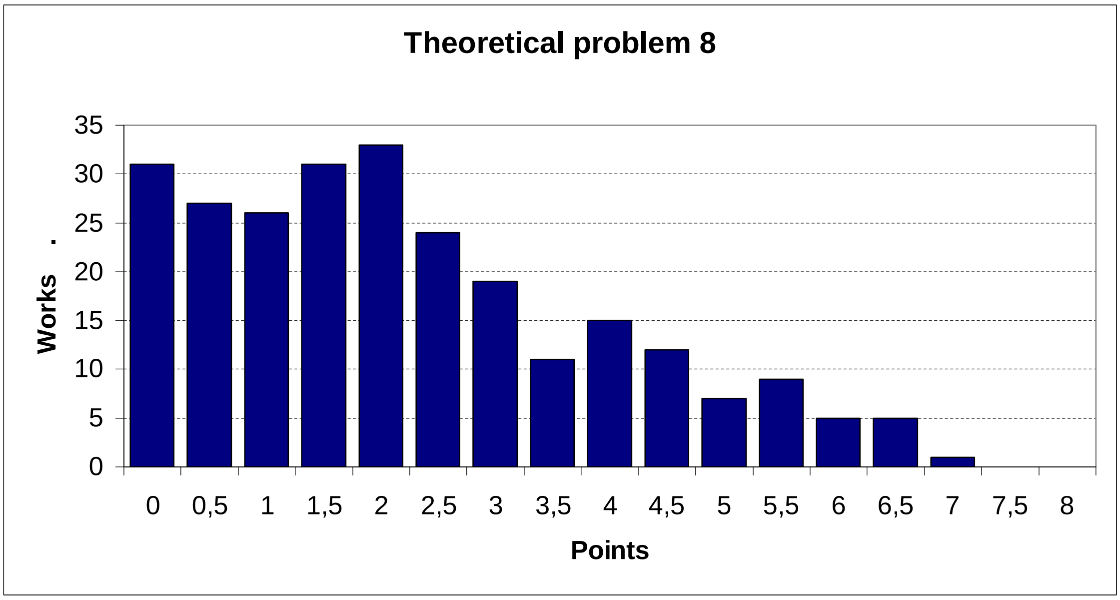

Theoretical problem 3
Works
70
60
50
40
30
20
10
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7
Points

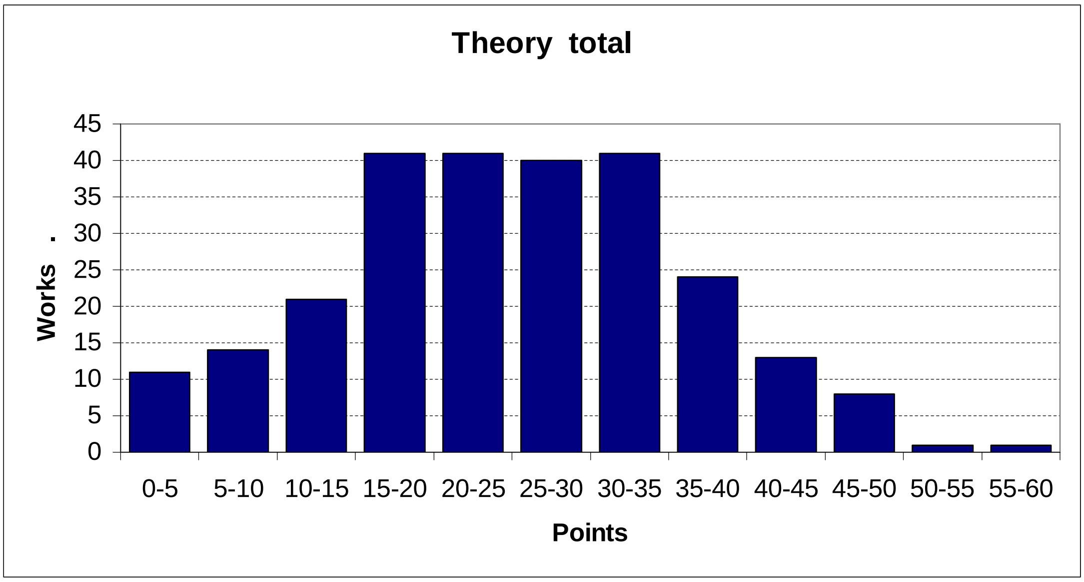

Theoretical problem 4
Works
Points
45
40
35
30
25
20
15
10
5
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5 8

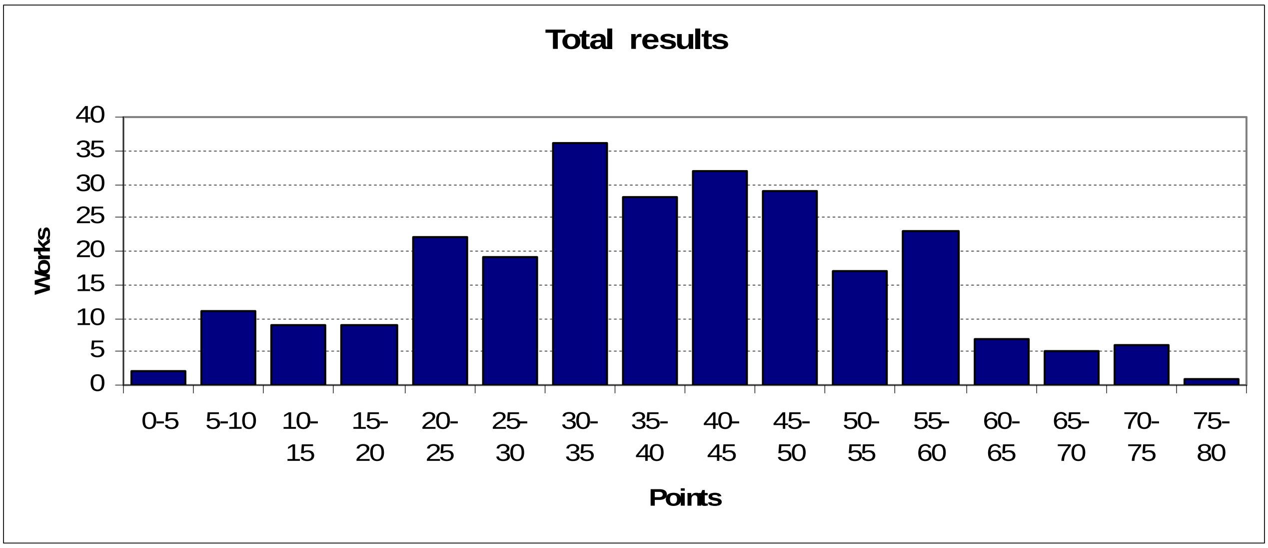

Theoretical problem 5
Works
Points
50
45
40
35
30
25
20
15
10
5
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5


Theoretical problem 6
Works
Points
40
35
30
25
20
15
10
5
0
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7


Theoretical problem 7
Works
Points
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5
0 10 20 30 40 50 60


Theoretical problem 8
Works
Points
0 0,5 1 1,5 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5 8
0 5 10 15 20 25 30 35


Theory total
Works
Points
0-5 5-10 10-15 15-20 20-25 25-30 30-35 35-40 40-45 45-50 50-55 55-60
0 5 10 15 20 25 30 35 40 45



Total results
Works
Points
40
35
30
25
20
15
10
5
0
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80

RESULTS PER STUDENT

Rank	Name	Country	Practical exam (max 40)	Theoretical exam (max 60)	Total (max 100)	Medal
1	Lei XU	China	19.771	56.300	76.071	Gold
2	Yuan FANG	China	25.768	47.541	73.309	Gold
3	Leonid ROMASHOV	Russian Federation	32.556	39.712	72.267	Gold
4	Vasiliy VOROBYEV	Russian Federation	28.200	43.408	71.609	Gold
5	Zi-yang ZHANG	China	20.397	50.192	70.588	Gold
6	Ying Yu HO	Chinese Taipei	23.385	47.016	70.401	Gold
7	Dimitry Ur'evic LOUTCHKO	Germany	26.113	44.115	70.228	Gold
8	Jae Soo KIM	Korea Republic	35.000	34.721	69.721	Gold
9	Simon GOURDIN-BERTIN	France	27.457	40.529	67.986	Gold
10	Tae Gon OH	Korea Republic	22.718	45.027	67.745	Gold
11	Wei-Lun HUANG	Chinese Taipei	23.136	44.214	67.349	Gold
12	Dawid Grzegorz LICHOSYT	Poland	37.806	27.458	65.264	Gold
13	Krzysztof Cezary KOSINSKI	Poland	28.209	35.500	63.710	Gold
14	Le YANG	China	13.729	49.136	62.865	Gold
15	Stanislav TEREHOV	Russian Federation	25.214	37.564	62.778	Gold
16	Philipp Albert STEININGER	Germany	31.457	30.621	62.078	Gold
17	Bavorn HONGSRICHINDA	Thailand	32.136	29.501	61.638	Gold
18	Eugeny NEKHOROSHEV	Russian Federation	12.991	48.481	61.472	Gold
19	Wojciech Dominik MAGON	Poland	23.189	37.745	60.935	Gold
20	Chang Ho LEE	Korea Republic	22.308	37.602	59.911	Gold
21	Hande BOYACI	Turkey	26.934	32.959	59.893	Gold
22	Sumit SOMANI	India	16.191	43.569	59.759	Gold
23	Soham MEHTA	India	13.961	45.797	59.757	Gold
24	Martin LUKACISIN	Slovakia	26.865	32.135	59.000	Gold
25	Gyula PALFY	Hungary	19.153	39.712	58.866	Gold
26	Karolis LEONAVICIUS	Lithuania	25.819	32.580	58.399	Gold
27	Minh Nguyen Thi NGOC	Vietnam	11.198	47.043	58.241	Gold
28	Aurimas VYSNIAUSKAS	Lithuania	23.883	34.212	58.095	Gold
29	Hyeonjin BAE	Canada	26.640	31.362	58.003	Gold
30	Przemyslaw Krzysztof TREDAK	Poland	19.577	38.006	57.582	Gold
31	Ehsan SHABANI	Iran	28.640	28.783	57.423	Gold
32	Kai-Jui CHANG	Chinese Taipei	17.192	40.002	57.194	Silver
33	Tanatorn KHOTAVIVATTANA	Thailand	16.211	40.858	57.069	Silver
34	Samvel BARDAKHCHYAN	Armenia	15.005	41.874	56.878	Silver
35	Erik ANDRIS	Slovakia	28.207	28.495	56.701	Silver
36	Andres LAAN	Estonia	18.755	37.569	56.324	Silver
37	Dzianis HRAMAZDOU	Belarus	22.505	33.778	56.283	Silver
38	Frank Meng LIN	Chinese Taipei	18.174	37.600	55.774	Silver
39	Ostap CHERVAK	Ukraine	16.959	38.429	55.388	Silver
40	Brian Kihoon LEE	United States	15.090	40.156	55.246	Silver
41	Ctirad CERVINKA	Czech Republic	27.686	27.448	55.134	Silver
42	Andrew TULLOCH	Australia	18.304	36.723	55.027	Silver
43	Justin KOH	United States	25.441	29.480	54.921	Silver
44	Boris FACKOVEC	Slovakia	22.485	32.361	54.846	Silver
45	Ha Phan Tran HONG	Vietnam	12.005	42.435	54.439	Silver
46	Vikas PRAJAPATI	India	13.814	40.031	53.845	Silver
47	Attila LOVAS	Hungary	26.400	26.948	53.348	Silver

48	Narek DSHKHUNYN	Armenia	4.345	48.776	53.121	Silver
49	Alexander PUCHHAMMER	Austria	20.593	32.482	53.075	Silver
50	Matthew James CLIFFE	United Kingdom	14.930	38.144	53.074	Silver
51	Zeqi YANG	Singapore	16.398	36.193	52.591	Silver
52	Yerdos ORDABAYEV	Kazakhstan	20.921	31.572	52.493	Silver
53	Frederick Robert William Meath MANNERS	United Kingdom	17.898	34.542	52.44	Silver
54	Jonathan LIN	New Zealand	26.423	25.257	51.679	Silver
55	Petr HOSEK	Czech Republic	21.159	30.501	51.661	Silver
56	Pornchai KAEWSAPSAK	Thailand	14.586	35.859	50.445	Silver
57	Assaf Avraham SHAPIRA	Israel	19.610	30.628	50.238	Silver
58	Zhivko Atanasov GEORGIEV	Bulgaria	26.508	23.691	50.199	Silver
59	Lorinc SARKANY	Hungary	20.169	29.837	50.005	Silver
60	Stefan Michael PUSCH	Germany	14.908	35.053	49.961	Silver
61	Teuku Mahfuzh Aufar KARI	Indonesia	19.428	30.374	49.802	Silver
62	Vasile GRAUR	Moldova	26.640	23.153	49.793	Silver
63	Bernardas MORKUNAS	Lithuania	12.547	37.061	49.608	Silver
64	Jong Soo YOON	Korea Republic	10.165	39.100	49.265	Silver
65	Kenneth BREWER	United States	14.651	34.210	48.861	Silver
66	Muhamad FAIZ	Indonesia	12.228	36.543	48.770	Silver
67	Ioan Teodor TROTUS	Romania	12.031	36.713	48.744	Silver
68	Alena VASKOVA	Belarus	17.046	31.173	48.219	Silver
69	Andi KIPPER	Estonia	22.559	25.525	48.084	Silver
70	Stephan PRIBITZER	Austria	25.128	22.485	47.613	Silver
71	Kartik RAMESH	Australia	12.765	34.793	47.558	Silver
72	Vlad Alexandru PUSCASU	Romania	16.199	31.328	47.527	Silver
73	Kaveh MATINKHOO	Iran	15.477	31.912	47.388	Silver
74	Chuan Zheng LEE	New Zealand	21.221	25.880	47.101	Silver
75	Thais Macedo Bezerra Terceiro JORGE	Brazil	6.805	40.260	47.064	Silver
76	Balint BALAZS	Hungary	21.647	25.160	46.807	Silver
77	Jan KOGOJ	Slovenia	11.955	34.755	46.71	Silver
78	Vincenzo GRANDE	Italy	15.437	31.064	46.501	Silver
79	Ionut Gabriel DUMITRU	Romania	11.135	35.354	46.489	Silver
80	Linh Bui LE	Vietnam	12.571	33.874	46.445	Silver
81	Christian OBERENDER	Germany	14.951	31.469	46.420	Silver
82	Kainar KAMALOV	Kyrgyzstan	13.044	33.033	46.077	Silver
83	Jan BITENC	Slovenia	17.450	28.546	45.996	Silver
84	Benjamin CHEN	Singapore	16.318	29.592	45.909	Silver
85	Matias Daniel Gomez ELIAS	Argentina	15.446	30.324	45.771	Silver
86	Oscar Carl Gunnar GRANBERG	Sweden	23.490	22.188	45.677	Silver
87	Techin CHULADESA	Thailand	12.103	33.544	45.647	Silver
88	Gabriel Eduardo Sanoja LOPEZ	Venezuela	26.834	18.351	45.185	Bronze
89	Mihails ARHANGELSKIS	Latvia	7.063	37.904	44.967	Bronze
90	Christian MARBOE	Denmark	21.828	23.029	44.857	Bronze
91	Derek Steven Hung-Che CHAN	United Kingdom	10.785	34.012	44.797	Bronze
92	Takashi HIROI	Japan	7.035	37.491	44.526	Bronze
93	Ayana BADRAKOVA	Kazakhstan	16.875	27.297	44.172	Bronze
94	Volodymyr TKACHENKO	Ukraine	13.031	30.852	43.883	Bronze
95	Rafael de Cesaris Araujo TAVARES	Brazil	11.694	32.007	43.701	Bronze
96	Shabnam SHARIFZADEH	Iran	15.455	28.165	43.620	Bronze
97	Florian LANGMANN	Austria	11.869	31.661	43.529	Bronze
98	Raoul ROSENTHAL	Netherlands	24.573	18.952	43.525	Bronze
99	Ahmet Selim HAN	Turkey	14.401	28.972	43.373	Bronze

100	Naru TANAKA	Japan	6.453	36.910	43.363	Bronze
101	Vincentius Jeremy SUHARDI	Indonesia	17.791	25.311	43.102	Bronze
102	Jun Yan GOH	Malaysia	25.190	17.864	43.054	Bronze
103	Shotaro TSUNODA	Japan	7.017	35.679	42.696	Bronze
104	Taavi PUNGAS	Estonia	14.557	28.097	42.654	Bronze
105	Arshavir GHAHRAMANYAN	Armenia	0.900	41.616	42.516	Bronze
106	Kirill POLISCHUK	Ukraine	8.118	34.367	42.485	Bronze
107	Gonzalo Jose MUNAR	Argentina	20.343	22.106	42.449	Bronze
108	Guang Jun Joseph LIM	Singapore	11.426	30.918	42.344	Bronze
109	Andrew Brian CAIRNS	Ireland	18.006	24.284	42.290	Bronze
110	Lucia Domenica MEIER	Switzerland	22.642	19.641	42.283	Bronze
111	Thorbjørn Juul MORSING	Denmark	24.159	17.954	42.112	Bronze
112	Dauren KALIYEV	Kazakhstan	18.433	23.598	42.031	Bronze
113	Tsimafei BALOTNIK	Belarus	15.347	26.017	41.364	Bronze
114	Zijun (Jim) GE	Australia	7.476	33.874	41.350	Bronze
115	Zhanbolat ZHOLGELDIYEV	Kazakhstan	14.752	26.473	41.225	Bronze
116	Serdar ROZYYEV	Turkmenistan	17.227	23.638	40.865	Bronze
117	Shaina KHAN	Pakistan	20.955	19.891	40.847	Bronze
118	Petr JURIK	Czech Republic	15.377	25.109	40.486	Bronze
119	Olha BALABON	Ukraine	6.926	33.471	40.398	Bronze
120	Dan PENG	Canada	14.376	25.672	40.048	Bronze
121	WILLIAM	Indonesia	8.977	30.489	39.466	Bronze
122	Romāns ČAPLINSKIS	Latvia	12.821	26.535	39.356	Bronze
123	Liudmila KUSHNIR	Belarus	4.124	34.946	39.071	Bronze
124	Elise DUBOUE-DIJON	France	13.223	25.577	38.800	Bronze
125	Batyr GARLYYEV	Turkmenistan	11.647	27.108	38.755	Bronze
126	Chin Heng GAN	Singapore	10.653	28.078	38.731	Bronze
127	Henrik SOENSTEBY	Norway	19.194	19.266	38.460	Bronze
128	Immanuel Ilavarasan THOMAS	India	7.641	30.614	38.255	Bronze
129	Daniel Enrique Cardenas ARMAS	Venezuela	17.315	20.688	38.003	Bronze
130	Simone CALVELLO	Italy	11.900	25.906	37.806	Bronze
131	Thomas Ashton Christopher WONG	New Zealand	15.165	22.590	37.755	Bronze
132	Ivan OGIBALOV	Estonia	20.033	17.698	37.731	Bronze
133	Khursand YOROV	Tajikistan	6.462	31.250	37.712	Bronze
134	Ingrid Cristiana VREJA	Romania	8.593	29.015	37.608	Bronze
135	Ivanka Rosenova ZHIVKOVA	Bulgaria	12.109	25.325	37.435	Bronze
136	Taneli Toivo Hermanni RAJALA	Finland	15.913	21.495	37.408	Bronze
137	Muhamad Azri Muhamad MARICAN	Malaysia	16.076	21.185	37.261	Bronze
138	Gah Hung LEE	Malaysia	13.741	23.358	37.098	Bronze
139	Jorio Almino de Alencar Arrais MOTA	Brazil	10.298	26.788	37.086	Bronze
140	Michael James PLUNKETT	New Zealand	9.372	27.179	36.551	Bronze
141	Lubica KRAUSKOVA	Slovakia	15.294	21.194	36.488	Bronze
142	Nicholas MOULAF	Australia	5.543	30.779	36.322	Bronze
143	Jaroslav ZAK	United Kingdom	8.125	28.067	36.191	Bronze
144	Victor Lopez FERRANDO	Spain	16.276	19.873	36.149	Bronze
145	Hubert KALAUS	Austria	13.146	22.585	35.731	Bronze
146	Dogukan DIKMEN	Turkey	4.730	30.941	35.672	Bronze
147	Irena MATKOVIČ	Slovenia	6.191	29.430	35.621	Bronze
148	Kazuki YAMAGUCHI	Japan	12.328	23.116	35.444	Bronze
149	Anita PABANI	Pakistan	15.947	18.986	34.933	Bronze
150	Manuel Garcia RICARDO	Cuba	10.006	24.846	34.852	Bronze
151	Max HAFLIGER	Switzerland	5.936	28.640	34.575	Bronze

152	Sofia IZMAILOV	United States	12.278	22.193	34.471	Bronze
153	Mathijs de JONG	Netherlands	17.322	17.121	34.443	Bronze
154	Luciano Hector DI STEFANO	Argentina	12.951	21.413	34.364	Bronze
155	Itamar Avraham David SHAMAI	Israel	8.463	25.672	34.135	Bronze
156	Cristiana FANCIULLO	Italy	15.728	17.914	33.643	Bronze
157	Muradov NURMUHAMMET	Turkmenistan	7.700	25.691	33.391	Bronze
158	Pablo Gustavo LEVRAND	Argentina	11.167	22.168	33.335	Bronze
159	Sergio Fonseca CHITICA	Mexico	12.978	20.035	33.013	Honor. Mention
160	Roberta POCEVICIUTE	Lithuania	8.430	24.572	33.002	Honor. Mention
161	Quentin LEFEBVRE	France	4.698	28.219	32.917	Honor. Mention
162	Andreas FRUTIGER	Switzerland	17.922	14.839	32.761	Honor. Mention
163	Manh Le DINH	Vietnam	4.047	28.585	32.632	Honor. Mention
164	Amirhady KAMKARAMOLI	Iran	9.323	23.252	32.575	Honor. Mention
165	Geir Haakon BECKSTROEM	Norway	11.213	21.347	32.560	Honor. Mention
166	Javzansuren NORVANCHIG	Mongolia	19.940	12.369	32.309	Honor. Mention
167	Umed BOLTAEV	Tajikistan	6.581	25.623	32.204	Honor. Mention
168	Sabyrbek ZHEENTAEV	Kyrgyzstan	11.125	21.073	32.198	Honor. Mention
169	Jose Enrique Robles SOTO	Mexico	9.053	23.109	32.162	
170	Vincenzo SPALLUTO	Italy	19.643	12.481	32.124	
171	Juraj AHEL	Croatia	10.906	21.088	31.994	
172	Dan Liraz LIDJI	Israel	10.623	21.332	31.955	
173	Christiaan Alwin DOUMA	Netherlands	11.891	19.908	31.800	
174	Alberto Garcia BOSQUE	Spain	10.887	20.903	31.790	
175	Luis Alberto Ypanaque ROCHA	Peru	13.484	18.050	31.533	
176	Andri Vilberg ORRASON	Iceland	7.558	23.597	31.155	
177	Jia CHEN	Netherlands	13.756	17.073	30.830	
178	Ivana BREKALO	Croatia	6.885	23.812	30.698	
179	Benjamin BOUSQUET	France	10.071	20.369	30.440	
180	Daria Ewa STRUSKA	Sweden	13.226	17.060	30.285	
181	Haleluya SAGIT	Israel	14.383	15.827	30.209	
182	Michalis ROSSIDES	Cyprus	14.549	15.565	30.114	
183	Martina FEYZRAKHMANOVA	Ireland	6.592	23.499	30.091	
184	Sotirios CHRISTODOULOU	Greece	15.933	14.089	30.021	
185	Mehmet VURAL	Turkey	4.770	24.801	29.571	
186	Aminatulmunirah KASIM	Malaysia	14.217	14.921	29.138	
187	Cristhian Luis Canari CHUMPITAZ	Peru	10.133	18.935	29.069	
188	Miha Emerik HABIC	Slovenia	9.107	19.950	29.057	
189	Ivan PREPOLEC	Croatia	10.678	18.349	29.027	
190	Andres Suarez VELAZQUEZ	Spain	9.964	18.946	28.910	
191	Zamirbek AKIMBEKOV	Kyrgyzstan	6.850	21.749	28.599	
192	Shervin GHAFOURI-TABRIZI	Canada	5.318	22.533	27.852	
193	Veaceslav VIERU	Moldova	10.240	17.595	27.835	
194	Stella Lucie RIAD	Sweden	9.659	17.868	27.527	
195	Urandelger TUVSHINDORJ	Mongolia	15.717	11.531	27.248	
196	Janne Valo Verner HENRIKSSON	Finland	14.805	11.925	26.729	
197	Konstantinos HADJIPETROU	Cyprus	9.872	16.678	26.550	
198	Patrick Michael O'SULLIVAN	Ireland	7.094	18.803	25.897	
199	Hordur Freyr YNGVASON	Iceland	9.179	16.564	25.743	
200	Pāvels ZUBOVIČS	Latvia	7.373	17.985	25.358	
201	Quentin HISETTE	Belgium	15.442	9.809	25.251	
202	Petr STADLBAUER	Czech Republic	11.430	13.603	25.033	
203	Karl NJALSSON	Iceland	7.899	17.130	25.029	
204	Ivan BARUN	Croatia	5.171	19.810	24.981	

205	Axel Nils Ola GOTTFRIES	Sweden	10.125	14.801	24.927	
206	John Christopher JANETZKO	Canada	4.758	20.104	24.862	
207	Johan Yuan WANG	Norway	2.883	21.874	24.756	
208	Tina KANSTRUP	Denmark	8.823	15.645	24.468	
209	Jose Ernando Sousa FILHO	Brazil	2.863	21.546	24.409	
210	Juan Ivan GOMEZ-PERALTA	Mexico	9.277	14.958	24.234	
211	Panagiotis PALANTAS	Greece	5.106	18.826	23.932	
212	Grigoris KATSIOLIDIS	Cyprus	12.632	10.737	23.369	
213	Charis Antonis ANTONIOU	Cyprus	8.125	15.176	23.301	
214	Ioannis BOTIS	Greece	7.950	15.092	23.042	
215	Grellan Jerome Kevin TUOHY	Ireland	10.116	12.747	22.863	
216	Vanessa LOODTS	Belgium	6.211	16.556	22.767	
217	Frederic COTTIER	Switzerland	7.529	14.979	22.508	
218	Alexandru CARTALEANU	Moldova	5.053	17.351	22.403	
219	Alberto Sanchez MOLERO	Spain	9.554	12.339	21.893	
220	Shahzad IQBAL	Pakistan	4.009	17.060	21.069	
221	Joseph Hernan Pena ECHEVARRIA	Peru	4.056	16.917	20.973	
222	Battulga BYAMBASUREN	Mongolia	7.648	13.250	20.898	
223	Leonid BIBIN	Moldova	4.891	15.658	20.549	
224	David Van CAUWENBERGE	Belgium	6.442	14.073	20.515	
225	Saidullo SULAYMONZODA	Tajikistan	0.200	20.001	20.201	
226	Hamza Khan SHAHBAZI	Pakistan	3.236	16.374	19.61	
227	Vesteinn SNAEBJARNARSON	Iceland	8.010	11.492	19.502	
228	Raul Joao de Sousa PEREIRA	Portugal	1.700	17.775	19.475	
229	Jānis JERMAKS	Latvia	5.723	12.879	18.602	
230	Carlos Leonel Ahumada MANUEL	Mexico	4.001	14.163	18.164	
231	Khusrav OLIMI	Tajikistan	7.695	9.478	17.174	
232	Christoffer NORN	Denmark	6.830	9.317	16.147	
233	Camilla ESPEDAL	Norway	6.282	8.980	15.262	
234	Stefan Dimitrov KADIYSKY	Bulgaria	3.777	11.429	15.206	
235	Linus Benjamin TÖRNQVIST	Finland	5.883	8.921	14.803	
236	Jorn WALSCHARTS	Belgium	6.200	8.248	14.448	
237	Mari Liisa TEINILÄ	Finland	6.281	8.021	14.302	
238	Gergana Sasheva VALCHEVA	Bulgaria	0.930	13.367	14.297	
239	Rui Emanuel Ferreira da SILVA	Portugal	3.864	9.715	13.579	
240	Joaquin GRASSI	Uruguay	3.691	9.487	13.178	
241	Rui Filipe Goncalves APOSTOLO	Portugal	4.770	7.717	12.487	
242	Memmed MIRZEYEV	Azerbaijan	12.458	0.000	12.458	
243	Argyroula LAVI	Greece	7.598	4.483	12.081	
244	Nicat MUSAYEV	Azerbaijan	9.665	0.000	9.665	
245	Sebastian BARCARDAL	Uruguay	2.326	7.189	9.515	
246	Rui Filipe Lebres LOPES	Portugal	1.450	7.862	9.312	
247	Uyanga DAGVADORJ	Mongolia	2.093	6.712	8.805	
248	Osamah Altaib SAFWAN	Saudi Arabia	0.450	7.233	7.683	
249	Diego OTERO	Uruguay	3.388	4.266	7.655	
250	Sebastian FIAMENE	Uruguay	2.326	4.011	6.336	
251	Mohammed Abdullah ALGASIM	Saudi Arabia	1.960	4.323	6.283	
252	Ibrahim Abdullah Ba JAAFR	Saudi Arabia	1.928	3.844	5.772	
253	Ataallah Naif ALHARBI	Saudi Arabia	1.150	4.590	5.740	
254	Abdulla AHMADOV	Azerbaijan	5.365	0.000	5.365	
255	Sohbet HOJAMUHAMMEDOV	Turkmenistan	0.000	4.352	4.352	
256	Orxan RZAYEV	Azerbaijan	0.233	0.000	0.233	

DETAILED RESULTS PER COUNTRY

Country	Name	P_1	P_2	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Practice	Theory	Total	Rank	Medal
Argentina	Matias Daniel Gomez ELIAS	4.963	10.483	5.571	3.636	4.846	5.024	3.200	2.838	3.103	2.105	15.446	30.324	45.771	85	Silver
	Gonzalo Jose MUNAR	2.093	18.250	2.286	4.000	3.769	3.840	3.500	3.216	0.569	0.926	20.343	22.106	42.449	107	Bronze
	Luciano Hector DI STEFANO	8.951	4.000	5.000	0.727	4.128	3.520	1.700	5.108	0.724	0.505	12.951	21.413	34.364	154	Bronze
	Pablo Gustavo LEVRAND	6.167	5.000	3.857	6.182	3.410	5.120	0.000	0.946	0.000	2.653	11.167	22.168	33.335	158	Bronze
Armenia	Samvel BARDAKHCHYAN	13.605	1.400	6.714	7.091	7.000	3.456	6.200	2.270	7.500	1.642	15.005	41.874	56.878	34	Silver
	Narek DSHKHUNYN	1.395	2.950	7.000	8.000	7.000	5.888	6.700	4.541	7.500	2.147	4.345	48.776	53.121	48	Silver
	Arshavir GHAHRAMANYAN	0.000	0.900	7.000	6.182	6.641	2.080	6.700	1.892	7.500	3.621	0.900	41.616	42.516	105	Bronze
Australia	Andrew TULLOCH	8.721	9.583	6.286	5.818	6.282	4.000	0.200	4.919	4.966	4.253	18.304	36.723	55.027	42	Silver
	Kartik RAMESH	7.255	5.510	5.857	3.455	4.128	5.280	2.800	4.919	4.397	3.958	12.765	34.793	47.558	71	Silver
	Zijun (Jim) GE	2.209	5.267	4.143	4.909	4.487	5.280	2.100	4.919	3.362	4.674	7.476	33.874	41.350	114	Bronze
	Nicholas MOULAF	2.093	3.450	5.429	4.182	5.205	2.208	2.100	5.297	1.810	4.547	5.543	30.779	36.322	142	Bronze
Austria	Alexander PUCHHAMMER	8.893	11.700	4.714	4.000	5.026	4.000	4.200	5.676	1.034	3.832	20.593	32.482	53.075	49	Silver
	Stephan PRIBITZER	19.111	6.017	3.571	3.273	4.128	3.040	1.700	4.162	1.810	0.800	25.128	22.485	47.613	70	Silver
	Florian LANGMANN	4.419	7.450	5.286	2.000	3.410	2.880	3.600	4.730	6.766	2.989	11.869	31.661	43.529	97	Bronze
	Hubert KALAUS	6.746	6.400	3.286	0.364	4.128	1.920	1.700	1.514	7.190	2.484	13.146	22.585	35.731	145	Bronze
Azerbaijan	Memmed MIRZEYEV	2.558	9.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.458	0.000	12.458	242	
	Nicat MUSAYEV	0.465	9.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.665	0.000	9.665	244	
	Abdulla AHMADOV	0.465	4.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.365	0.000	5.365	254	
	Orxan RZAYEV	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233	0.000	0.233	256	
Belarus	Dzianis HRAMAZDOU	8.605	13.900	5.857	5.636	4.308	6.880	3.700	4.162	0.414	2.821	22.505	33.778	56.283	37	Silver
	Alena VASKOVA	8.296	8.750	6.429	4.727	3.949	5.600	2.800	3.973	1.759	1.937	17.046	31.173	48.219	68	Silver
	Tsimafei BALOTNIK	11.447	3.900	4.000	3.273	5.205	4.160	3.500	3.500	0.569	1.811	15.347	26.017	41.364	113	Bronze
	Liudmila KUSHNIR	2.674	1.450	6.714	5.091	4.846	4.000	1.200	5.297	2.534	5.263	4.124	34.946	39.071	123	Bronze

Belgium	Quentin HISETTE	5.642	9.800	4.143	0.727	0.359	1.600	0.700	1.324	0.155	0.800	15.442	9.809	25.251	201	
	Vanessa LOODTS	6.211	0.000	5.286	2.909	0.538	0.544	1.200	3.784	0.569	1.726	6.211	16.556	22.767	216	
	David Van CAUWENBERGE	3.442	3.000	3.286	1.091	1.436	2.112	1.200	3.405	0.828	0.716	6.442	14.073	20.515	224	
	Jorn WALSCHARTS	0.000	6.200	3.143	0.091	0.000	2.176	0.000	2.838	0.000	0.000	6.200	8.248	14.448	236	
Brazil	Thais Macedo Bezerra Terceiro JORGE	3.605	3.200	5.000	5.091	5.205	4.160	5.000	5.297	7.138	3.368	6.805	40.260	47.064	75	Silver
	Rafael de Cesaris Araujo TAVARES	1.744	9.950	5.571	5.091	5.026	4.800	1.200	4.351	4.241	1.726	11.694	32.007	43.701	95	Bronze
	Jorio Almino de Alencar Arrais MOTA	7.698	2.600	5.571	1.091	5.205	4.160	1.900	6.054	0.828	1.979	10.298	26.788	37.086	139	Bronze
	Jose Ernando Sousa FILHO	1.163	1.700	4.571	2.545	3.949	3.776	1.700	4.162	0.000	0.842	2.863	21.546	24.409	209	
Bulgaria	Zhivko Atanasov GEORGIEV	9.158	17.350	1.429	2.364	4.487	4.608	2.700	4.635	0.310	3.158	26.508	23.691	50.199	58	Silver
	Ivanka Rosenova ZHIVKOVA	2.209	9.900	4.857	2.000	6.103	2.720	2.500	3.878	2.172	1.095	12.109	25.325	37.435	135	Bronze
	Stefan Dimitrov KADIYSKY	2.977	0.800	2.000	0.364	3.410	1.920	2.500	0.000	0.983	0.253	3.777	11.429	15.206	234	
	Gergana Sasheva VALCHEVA	0.930	0.000	5.286	1.818	0.718	2.464	1.000	2.081	0.000	0.000	0.930	13.367	14.297	238	
Canada	Hyeonjin BAE	12.307	14.333	5.286	5.273	4.487	1.504	3.500	4.351	2.793	4.168	26.640	31.362	58.003	29	Gold
	Dan PENG	10.476	3.900	5.143	4.545	5.744	1.574	1.700	3.595	0.466	2.905	14.376	25.672	40.048	120	Bronze
	Shervin GHAFOURI-TABRIZI	4.208	1.110	6.714	2.182	5.923	3.200	1.000	1.703	1.138	0.674	5.318	22.533	27.852	192	
	John Christopher JANETZKO	3.558	1.200	4.714	0.182	4.487	0.320	2.700	2.459	3.052	2.189	4.758	20.104	24.862	206	
China	Lei XU	3.721	16.050	7.000	8.000	7.000	7.200	5.900	6.811	7.190	7.200	19.771	56.300	76.071	1	Gold
	Yuan FANG	9.535	16.233	6.714	8.000	6.462	6.400	7.000	5.108	2.172	5.684	25.768	47.541	73.309	2	Gold
	Zi-yang ZHANG	14.047	6.350	5.571	5.818	5.923	6.720	6.200	6.243	7.190	6.526	20.397	50.192	70.588	5	Gold
	Le YANG	4.279	9.450	6.714	8.000	6.641	5.728	5.100	7.000	6.921	3.032	13.729	49.136	62.865	14	Gold
Chinese Taipei	Ying Yu HO	6.485	16.900	6.714	7.636	6.103	5.440	5.700	4.919	6.672	3.832	23.385	47.016	70.401	6	Gold
	Wei-Lun HUANG	15.669	7.467	6.143	5.455	4.487	6.560	5.100	5.676	4.267	6.526	23.136	44.214	67.349	11	Gold
	Kai-Jui CHANG	10.925	6.267	5.286	5.818	3.949	5.280	2.900	5.865	5.431	5.474	17.192	40.002	57.194	32	Silver
	Frank Meng LIN	7.624	10.550	6.714	5.818	4.846	4.160	5.100	4.919	4.190	1.853	18.174	37.600	55.774	38	Silver

Croatia	Juraj AHEL	3.256	7.650	5.571	2.455	2.692	1.120	1.200	3.973	0.414	3.663	10.906	21.088	31.994	171	
	Ivana BREKALO	2.385	4.500	6.143	1.455	4.487	3.360	2.800	3.784	0.310	1.474	6.885	23.812	30.698	178	
	Ivan PREPOLEC	6.894	3.783	4.143	1.091	4.308	6.240	2.000	0.568	0.000	0.000	10.678	18.349	29.027	189	
	Ivan BARUN	4.311	0.860	6.143	4.727	3.590	4.160	0.000	0.000	1.190	0.000	5.171	19.810	24.980	204	
Cuba	Manuel Garcia RICARDO	3.140	6.867	2.000	3.273	4.487	6.656	3.700	4.730	0.000	0.000	10.006	24.846	34.852	150	Bronze
Cyprus	Michalis ROSSIDES	11.939	2.610	3.286	2.727	4.487	1.862	1.000	1.892	0.310	0.000	14.549	15.565	30.114	182	
	Konstantinos HADJIPETROU	8.372	1.500	4.429	3.636	2.872	3.200	1.300	0.568	0.000	0.674	9.872	16.678	26.550	197	
	Grigoris KATSIOLIDIS	11.066	1.567	4.286	1.455	1.436	0.480	1.000	2.081	0.000	0.000	12.632	10.737	23.369	212	
	Charis Antonis ANTONIOU	2.558	5.567	4.143	0.818	2.333	2.528	2.200	3.027	0.000	0.126	8.125	15.176	23.301	213	
Czech Republic	Ctirad CERVINKA	17.386	10.300	5.857	6.182	3.410	2.880	1.000	3.027	1.345	3.747	27.686	27.448	55.134	41	Silver
	Petr HOSEK	5.476	15.683	6.143	0.000	4.128	4.736	2.000	4.730	5.017	3.747	21.159	30.501	51.661	55	Silver
	Petr JURIK	13.177	2.200	5.143	2.545	5.385	5.376	0.200	3.595	0.466	2.400	15.377	25.109	40.486	118	Bronze
	Petr STADLBAUER	3.930	7.500	1.429	0.000	2.333	2.560	2.900	2.838	0.828	0.716	11.430	13.603	25.033	202	
Denmark	Christian MARBOE	9.278	12.550	5.857	2.091	2.692	3.840	1.000	3.973	0.207	3.368	21.828	23.029	44.857	90	Bronze
	Thorbjørn Juul MORSING	10.659	13.500	4.286	0.727	4.846	2.560	1.000	3.784	0.414	0.337	24.159	17.954	42.112	111	Bronze
	Tina KANSTRUP	3.023	5.800	4.286	1.164	1.974	1.600	2.000	1.135	1.086	2.400	8.823	15.645	24.468	208	
	Christoffer NORN	6.830	0.000	1.571	0.727	0.718	2.886	1.900	1.514	0.000	0.000	6.830	9.317	16.147	232	
Estonia	Andres LAAN	9.955	8.800	6.143	2.364	5.744	4.800	5.200	3.973	6.103	3.242	18.755	37.569	56.324	36	Silver
	Andi KIPPER	12.059	10.500	4.714	0.909	5.026	4.480	0.500	3.784	5.017	1.095	22.559	25.525	48.084	69	Silver
	Taavi PUNGAS	3.907	10.650	5.429	5.455	5.205	1.760	2.200	4.730	0.414	2.905	14.557	28.097	42.654	104	Bronze
	Ivan OGIBALOV	11.733	8.300	4.429	1.091	4.308	1.120	0.700	3.784	1.552	0.716	20.033	17.698	37.731	132	Bronze
Finland	Taneli Toivo Hermanni RAJALA	6.047	9.867	5.571	1.818	3.949	3.136	2.400	2.649	0.414	1.558	15.913	21.495	37.408	136	Bronze
	Janne Valo Verner HENRIKSSON	8.605	6.200	3.857	0.364	1.615	3.040	1.000	1.324	0.724	0.000	14.805	11.925	26.729	196	
	Linus Benjamin TÖRNQVIST	3.083	2.800	3.286	0.182	0.000	0.480	1.000	3.973	0.000	0.000	5.883	8.921	14.803	235	
	Mari Liisa TEINILÄ	5.381	0.900	0.857	0.727	1.436	1.920	1.000	2.081	0.000	0.000	6.281	8.021	14.302	237	
France	Simon GOURDIN-BERTIN	9.607	17.850	6.143	6.909	6.641	6.080	4.500	5.486	0.517	4.253	27.457	40.529	67.986	9	Gold
	Elise DUBOUE-DIJON	4.613	8.610	5.571	2.909	6.282	5.120	2.000	1.514	1.086	1.095	13.223	25.577	38.800	124	Bronze
	Quentin LEFEBVRE	4.698	0.000	5.571	4.000	6.641	3.648	1.200	4.541	1.397	1.221	4.698	28.219	32.917	161	HM
	Benjamin BOUSQUET	8.721	1.350	3.857	1.818	4.846	1.702	2.000	3.595	1.034	1.516	10.071	20.369	30.440	179	

Germany	Dimitry Ur'evic LOUTCHKO	13.796	12.317	5.000	7.818	5.564	4.768	7.000	4.919	6.983	2.063	26.113	44.115	70.228	7	Gold
	Philipp Albert STEININGER	17.707	13.750	5.857	4.000	5.564	5.280	1.000	3.595	1.241	4.084	31.457	30.621	62.078	16	Gold
	Stefan Michael PUSCH	3.674	11.233	6.143	4.364	4.487	4.960	3.000	4.919	1.707	5.474	14.908	35.053	49.961	60	Silver
	Christian OBERENDER	7.851	7.100	4.571	4.545	4.128	6.720	1.800	4.351	0.931	4.421	14.951	31.469	46.420	81	Silver
Greece	Sotirios CHRISTODOULOU	0.233	15.700	4.429	3.273	3.410	0.000	0.200	1.135	0.000	1.642	15.933	14.089	30.021	184	
	Panagiotis PALANTAS	1.163	3.943	5.286	2.000	1.974	0.320	5.500	1.135	0.000	2.611	5.106	18.826	23.932	211	
	Ioannis BOTIS	0.000	7.950	5.429	0.364	5.923	0.000	0.200	1.703	0.000	1.474	7.950	15.092	23.042	214	
	Argyroula LAVI	0.698	6.900	0.857	1.091	0.359	0.870	0.000	0.000	0.000	1.305	7.598	4.483	12.080	243	
Hungary	Gyula PALFY	3.953	15.200	5.286	6.909	4.487	4.320	1.700	6.054	7.293	3.663	19.153	39.712	58.866	25	Gold
	Attila LOVAS	12.400	14.000	5.286	0.000	4.487	6.560	3.500	4.730	0.828	1.558	26.400	26.948	53.348	47	Silver
	Lorinc SARKANY	6.019	14.150	3.143	4.727	6.462	4.480	3.500	4.351	0.310	2.863	20.169	29.837	50.005	59	Silver
	Balint BALAZS	8.347	13.300	5.286	1.091	4.487	1.216	2.800	4.730	0.414	5.137	21.647	25.160	46.807	76	Silver
Iceland	Andri Vilberg ORRASON	2.558	5.000	6.286	4.000	4.846	3.936	0.000	2.649	0.828	1.053	7.558	23.597	31.155	176	
	Hordur Freyr YNGVASON	9.179	0.000	4.143	0.000	6.282	2.016	0.700	1.892	0.310	1.221	9.179	16.564	25.743	199	
	Karl NJALSSON	6.299	1.600	4.000	0.000	4.308	3.424	0.700	2.270	0.828	1.600	7.899	17.130	25.029	203	
	Vesteinn SNAEBJARNARSON	0.000	8.010	1.714	1.091	2.872	2.560	0.500	1.703	0.000	1.053	8.010	11.492	19.502	227	
India	Sumit SOMANI	2.791	13.400	6.000	7.636	4.487	6.400	3.400	6.054	4.707	4.884	16.191	43.569	59.759	22	Gold
	Soham MEHTA	8.561	5.400	6.714	6.000	5.923	5.760	5.100	5.865	5.845	4.589	13.961	45.797	59.757	23	Gold
	Vikas PRAJAPATI	1.814	12.000	6.429	8.000	4.846	6.560	3.200	6.243	2.690	2.063	13.814	40.031	53.845	46	Silver
	Immanuel Ilavarasan THOMAS	5.891	1.750	6.429	7.455	6.282	1.280	1.900	4.351	0.517	2.400	7.641	30.614	38.255	128	Bronze
Indonesia	Teuku Mahfuzh Aufar KARI	2.728	16.700	5.429	5.818	5.205	3.200	1.700	2.932	3.310	2.779	19.428	30.374	49.802	61	Silver
	Muhamad FAIZ	10.228	2.000	6.714	5.636	5.923	3.680	2.100	5.486	1.655	5.347	12.228	36.543	48.770	66	Silver
	Vincentius Jeremy SUHARDI	3.008	14.783	4.571	3.455	4.487	4.000	2.000	2.838	0.466	3.495	17.791	25.311	43.102	101	Bronze
	WILLIAM	6.927	2.050	4.857	6.545	5.923	4.704	1.300	3.973	1.966	1.221	8.977	30.489	39.466	121	Bronze
Iran	Ehsan SHABANI	11.640	17.000	6.143	2.909	4.128	3.840	3.900	4.919	2.017	0.926	28.640	28.783	57.423	31	Gold
	Kaveh MATINKHOO	6.427	9.050	5.000	7.273	4.487	2.880	4.000	4.351	0.931	2.989	15.477	31.912	47.388	73	Silver
	Shabnam SHARIFZADEH	8.605	6.850	5.286	4.364	4.128	3.040	4.500	4.351	0.517	1.979	15.455	28.165	43.620	96	Bronze
	Amirhady KAMKARAMOLI	3.023	6.300	5.429	3.091	3.410	3.680	0.000	3.216	0.931	3.495	9.323	23.252	32.575	164	HM

Ireland	Andrew Brian CAIRNS	3.256	14.750	2.714	5.818	4.128	3.520	2.000	3.216	1.034	1.853	18.006	24.284	42.290	109	Bronze
	Martina FEYZRAKHMANOVA	3.442	3.150	4.714	4.909	4.846	3.136	1.400	2.838	1.319	0.337	6.592	23.499	30.091	183	
	Patrick Michael O'SULLIVAN	1.860	5.233	4.857	3.273	4.487	2.720	1.200	1.703	0.310	0.253	7.094	18.803	25.897	198	
	Grellan Jerome Kevin TUOHY	3.256	6.860	3.857	0.182	2.692	0.736	1.000	1.703	0.724	1.853	10.116	12.747	22.863	215	
Israel	Assaf Avraham SHAPIRA	8.210	11.400	6.714	7.636	4.308	4.320	3.600	1.986	0.000	2.063	19.610	30.628	50.238	57	Silver
	Itamar Avraham David SHAMAI	2.163	6.300	5.143	6.545	5.923	4.096	1.000	2.459	0.000	0.505	8.463	25.672	34.135	155	Bronze
	Dan Liraz LIDJI	8.140	2.483	3.857	2.182	6.282	0.480	2.500	3.405	2.121	0.505	10.623	21.332	31.955	172	
	Haleluya SAGIT	11.433	2.950	3.857	1.091	3.949	2.560	0.900	2.459	0.000	1.011	14.383	15.827	30.209	181	
Italy	Vincenzo GRANDE	8.837	6.600	5.286	6.727	4.846	4.896	3.400	2.838	1.345	1.726	15.437	31.064	46.501	78	Silver
	Simone CALVELLO	4.650	7.250	3.571	3.636	4.487	3.200	2.700	5.297	1.034	1.979	11.900	25.906	37.806	130	Bronze
	Cristiana FANCIULLO	11.195	4.533	6.429	0.000	3.410	3.840	0.000	2.838	0.724	0.674	15.728	17.914	33.643	156	Bronze
	Vincenzo SPALLUTO	7.093	12.550	1.143	1.091	2.333	3.040	1.600	0.946	2.328	0.000	19.643	12.481	32.124	170	
Japan	Takashi HIROI	5.475	1.560	6.143	2.545	4.487	5.440	1.800	4.541	6.724	5.811	7.035	37.491	44.526	92	Bronze
	Naru TANAKA	4.853	1.600	6.429	4.182	6.282	2.720	4.500	5.486	2.679	4.632	6.453	36.910	43.363	100	Bronze
	Shotaro TSUNODA	6.217	0.800	5.857	8.000	6.641	3.840	1.700	4.824	1.448	3.368	7.017	35.679	42.696	103	Bronze
	Kazuki YAMAGUCHI	9.778	2.550	6.571	2.182	3.769	1.536	2.500	3.595	0.310	2.653	12.328	23.116	35.444	148	Bronze
Kazakhstan	Yerdos ORDABAYEV	13.721	7.200	6.143	5.818	7.000	4.256	2.100	3.973	0.724	1.558	20.921	31.572	52.493	52	Silver
	Ayana BADRAKOVA	4.975	11.900	5.000	7.091	5.923	4.320	0.000	3.405	0.000	1.558	16.875	27.297	44.172	93	Bronze
	Dauren KALIYEV	10.066	8.367	1.714	1.091	2.333	6.336	4.100	3.973	2.534	1.516	18.433	23.598	42.031	112	Bronze
	Zhanbolat ZHOLGELDIYEV	14.302	0.450	4.357	2.182	4.308	2.880	0.800	4.257	5.121	2.568	14.752	26.473	41.225	115	Bronze
Korea Republic	Jae Soo KIM	19.000	16.000	5.857	5.636	6.641	3.520	1.800	5.486	0.517	5.263	35.000	34.721	69.721	8	Gold
	Tae Gon OH	6.568	16.150	6.143	8.000	4.487	4.800	6.200	6.432	5.007	3.958	22.718	45.027	67.745	10	Gold
	Chang Ho LEE	3.558	18.750	6.714	8.000	4.487	3.200	1.600	5.865	4.241	3.495	22.308	37.602	59.911	20	Gold
	Jong Soo YOON	3.755	6.410	6.429	6.364	5.923	2.400	5.000	4.351	5.897	2.737	10.165	39.100	49.265	64	Silver
Kyrgyzstan	Kainar KAMALOV	7.501	5.543	5.571	3.818	3.231	4.736	5.500	2.649	6.517	1.011	13.044	33.033	46.077	82	Silver
	Sabyrbek ZHEENTAEV	3.225	7.900	2.143	1.818	5.744	4.096	3.100	2.459	0.155	1.558	11.125	21.073	32.198	168	HM
	Zamirbek AKIMBEKOV	0.000	6.850	3.429	1.091	3.410	4.096	3.700	2.838	0.828	2.358	6.850	21.749	28.599	191	

Latvia	Mihails ARHANGELSKIS	5.463	1.600	5.714	5.091	4.308	4.640	5.400	5.676	4.086	2.989	7.063	37.904	44.967	89	Bronze
	Romāns ČAPLINSKIS	7.971	4.850	1.429	0.182	5.564	5.440	3.600	5.676	1.655	2.989	12.821	26.535	39.356	122	Bronze
	Pāvels ZUBOVIČS	3.023	4.350	5.286	3.455	5.923	2.464	0.500	0.189	0.000	0.168	7.373	17.985	25.358	200	
	Jānis JERMAKS	3.023	2.700	2.000	0.364	2.333	3.744	1.600	2.838	0.000	0.000	5.723	12.879	18.602	229	
Lithuania	Karolis LEONAVICIUS	7.569	18.250	6.000	4.909	4.128	4.160	2.700	4.351	0.310	6.021	25.819	32.580	58.399	26	Gold
	Aurimas VYSNIAUSKAS	11.083	12.800	6.429	6.909	4.487	4.160	4.200	2.649	0.621	4.758	23.883	34.212	58.095	28	Gold
	Bernardas MORKUNAS	6.730	5.817	6.000	6.545	3.769	3.936	3.200	4.351	3.828	5.432	12.547	37.061	49.608	63	Silver
	Roberta POCEVICIUTE	5.430	3.000	5.143	4.909	4.487	3.360	2.700	3.973	0.000	0.000	8.430	24.572	33.002	160	HM
Malaysia	Jun Yan GOH	7.890	17.300	5.571	1.091	4.487	2.176	1.700	2.459	0.000	0.379	25.190	17.864	43.054	102	Bronze
	Muhamad Azri Muhamad MARICAN	7.326	8.750	5.143	4.182	1.974	3.040	1.000	3.405	0.672	1.768	16.076	21.185	37.261	137	Bronze
	Gah Hung LEE	2.791	10.950	5.571	0.727	4.487	2.976	2.500	4.541	0.155	2.400	13.741	23.358	37.098	138	Bronze
	Aminatulmunirah KASIM	7.817	6.400	2.857	0.909	2.692	2.400	1.000	2.459	0.414	2.189	14.217	14.921	29.138	186	
Mexico	Sergio Fonseca CHITICA	1.628	11.350	3.571	1.091	3.949	4.800	2.100	3.689	0.414	0.421	12.978	20.035	33.013	159	HM
	Jose Enrique Robles SOTO	8.153	0.900	4.714	1.091	3.949	3.840	1.200	5.676	1.966	0.674	9.053	23.109	32.162	169	
	Juan Ivan GOMEZ-PERALTA	1.977	7.300	1.714	0.727	4.846	3.200	1.900	1.703	0.362	0.505	9.277	14.958	24.234	210	
	Carlos Leonel Ahumada MANUEL	2.651	1.350	2.571	1.636	0.359	1.280	1.900	3.784	0.569	2.063	4.001	14.163	18.164	230	
Moldova	Vasile GRAUR	8.030	18.610	5.000	4.000	3.769	4.640	1.600	2.081	0.000	2.063	26.640	23.153	49.793	62	Silver
	Veaceslav VIERU	8.140	2.100	3.429	0.364	1.795	4.960	1.800	3.973	0.517	0.758	10.240	17.595	27.835	193	
	Alexandru CARTALEANU	2.519	2.533	3.286	0.000	2.513	3.520	2.800	3.027	0.310	1.895	5.053	17.351	22.403	218	
	Leonid BIBIN	4.891	0.000	6.000	0.000	3.590	2.976	1.200	1.892	0.000	0.000	4.891	15.658	20.549	223	
Mongolia	Javzansuren NORVANCHIG	13.023	6.917	3.857	3.273	0.538	2.560	0.500	1.135	0.000	0.505	19.940	12.369	32.309	166	HM
	Urandelger TUVSHINDORJ	0.000	15.717	2.286	2.727	2.513	0.768	1.000	1.514	0.724	0.000	15.717	11.531	27.248	195	
	Battulga BYAMBASUREN	0.698	6.950	2.000	1.818	1.615	3.680	1.200	2.270	0.414	0.253	7.648	13.250	20.898	222	
	Uyanga DAGVADORJ	2.093	0.000	1.857	0.727	0.359	2.080	1.000	0.378	0.310	0.000	2.093	6.712	8.805	247	
Netherlands	Raoul ROSENTHAL	7.773	16.800	1.429	2.909	4.667	2.240	2.200	3.595	0.776	1.137	24.573	18.952	43.525	98	Bronze
	Mathijs de JONG	4.372	12.950	2.143	1.818	3.590	4.160	1.500	3.784	0.000	0.126	17.322	17.121	34.443	153	Bronze
	Christiaan Alwin DOUMA	8.558	3.333	5.143	0.727	3.231	4.288	1.500	2.459	1.086	1.474	11.891	19.908	31.800	173	
	Jia CHEN	7.173	6.583	4.000	0.182	2.692	2.112	1.700	2.459	0.517	3.411	13.756	17.073	30.830	177	

New Zealand	Jonathan LIN	17.196	9.227	6.143	1.091	5.205	2.720	1.000	4.730	2.431	1.937	26.423	25.257	51.679	54	Silver
	Chuan Zheng LEE	5.221	16.000	6.143	0.182	3.769	3.520	1.200	4.919	0.000	6.147	21.221	25.880	47.101	74	Silver
	Thomas Ashton Christopher WONG	2.605	12.560	5.429	0.909	3.769	2.240	2.700	4.730	0.414	2.400	15.165	22.590	37.755	131	Bronze
	Michael James PLUNKETT	8.372	1.000	5.429	5.818	4.128	4.384	2.000	3.027	0.414	1.979	9.372	27.179	36.551	140	Bronze
Norway	Henrik SOENSTEBY	7.744	11.450	5.857	2.364	2.872	2.752	1.200	3.405	0.310	0.505	19.194	19.266	38.460	127	Bronze
	Geir Haakon BECKSTROEM	8.013	3.200	4.714	2.182	4.487	3.680	1.300	2.270	1.914	0.800	11.213	21.347	32.560	165	HM
	Johan Yuan WANG	0.233	2.650	5.286	5.091	3.590	2.560	1.200	2.649	0.362	1.137	2.883	21.874	24.756	207	
	Camilla ESPEDAL	5.482	0.800	4.714	0.182	0.538	0.480	0.500	1.892	0.000	0.674	6.282	8.980	15.262	233	
Pakistan	Shaina KHAN	8.755	12.200	2.000	3.273	1.974	3.680	1.500	2.081	1.552	3.832	20.955	19.891	40.847	117	Bronze
	Anita PABANI	8.937	7.010	4.000	0.909	3.410	4.800	1.500	2.649	1.086	0.632	15.947	18.986	34.933	149	Bronze
	Shahzad IQBAL	3.209	0.800	4.571	1.091	2.513	3.328	1.000	2.838	0.414	1.305	4.009	17.060	21.069	220	
	Hamza Khan SHAHBAZI	1.186	2.050	5.429	1.091	2.692	1.120	1.000	3.216	0.310	1.516	3.236	16.374	19.610	226	
Peru	Luis Alberto Ypanaque ROCHA	13.484	0.000	4.429	0.545	0.359	2.240	0.000	3.027	6.776	0.674	13.484	18.050	31.533	175	
	Cristhian Luis Canari CHUMPITAZ	0.000	10.133	1.714	0.364	6.282	3.776	1.600	3.595	0.931	0.674	10.133	18.935	29.069	187	
	Joseph Hernan Pena ECHEVARRIA	3.256	0.800	5.286	0.000	5.026	4.096	1.200	0.378	0.931	0.000	4.056	16.917	20.973	221	
Poland	Dawid Grzegorz LICHOSYT	19.256	18.550	4.571	1.091	4.846	3.872	4.400	4.730	1.759	2.189	37.806	27.458	65.264	12	Gold
	Krzysztof Cezary KOSINSKI	9.609	18.600	6.429	1.818	2.333	4.000	3.700	5.865	4.955	6.400	28.209	35.500	63.710	13	Gold
	Wojciech Dominik MAGON	8.639	14.550	6.143	8.000	4.308	3.040	1.900	5.014	6.352	2.989	23.189	37.745	60.935	19	Gold
	Przemyslaw Krzysztof TREDAK	10.667	8.910	5.571	8.000	4.128	6.240	2.300	4.730	0.931	6.105	19.577	38.006	57.582	30	Gold
Portugal	Raul Joao de Sousa PEREIRA	0.000	1.700	4.429	1.818	3.410	3.616	1.200	2.459	0.000	0.842	1.700	17.775	19.475	228	
	Rui Emanuel Ferreira da SILVA	0.814	3.050	3.286	1.091	1.256	2.240	1.000	0.000	0.000	0.842	3.864	9.715	13.579	239	
	Rui Filipe Goncalves APOSTOLO	4.170	0.600	0.571	1.091	0.897	2.656	0.700	1.135	0.414	0.253	4.770	7.717	12.487	241	
	Rui Filipe Lebres LOPES	0.000	1.450	3.000	2.182	1.077	0.320	0.000	0.946	0.000	0.337	1.450	7.862	9.312	246	

Romania	Ioan Teodor TROTUS	11.231	0.800	5.714	7.455	4.128	5.600	4.000	4.162	0.517	5.137	12.031	36.713	48.744	67	Silver
	Vlad Alexandru PUSCASU	9.149	7.050	5.857	4.727	6.282	3.616	4.100	5.297	1.448	0.000	16.199	31.328	47.527	72	Silver
	Ionut Gabriel DUMITRU	6.315	4.820	6.571	2.909	3.949	3.040	6.000	3.595	6.259	3.032	11.135	35.354	46.489	79	Silver
	Ingrid Cristiana VREJA	2.093	6.500	6.286	3.091	5.744	2.080	3.500	4.919	0.828	2.568	8.593	29.015	37.608	134	Bronze
Russian Federation	Leonid ROMASHOV	19.256	13.300	6.143	7.273	3.949	3.526	5.600	5.108	3.776	4.337	32.556	39.712	72.267	3	Gold
	Vasiliy VOROBYEV	13.340	14.860	6.000	4.000	3.769	7.360	3.700	5.865	6.103	6.611	28.200	43.408	71.609	4	Gold
	Stanislav TEREHOV	13.464	11.750	5.429	5.455	4.846	4.800	3.100	7.000	3.103	3.832	25.214	37.564	62.778	15	Gold
	Eugeny NEKHOROSHEV	9.191	3.800	6.857	5.818	4.487	5.440	7.200	6.432	6.983	5.263	12.991	48.481	61.472	18	Gold
Saudi Arabia	Osamah Altaib SAFWAN	0.000	0.450	1.714	0.727	1.256	0.013	1.500	1.230	0.414	0.379	0.450	7.233	7.683	248	
	Mohammed Abdullah ALGASIM	0.000	1.960	2.000	0.000	0.359	0.160	0.500	1.135	0.000	0.168	1.960	4.323	6.283	251	
	Ibrahim Abdullah Ba JAAFR	1.628	0.300	0.286	0.727	0.359	0.006	1.000	0.757	0.414	0.295	1.928	3.844	5.772	252	
	Ataallah Naif ALHARBI	0.000	1.150	1.143	0.000	0.359	0.006	1.000	1.703	0.000	0.379	1.150	4.590	5.740	253	
Singapore	Zeqi YANG	12.015	4.383	6.143	0.182	4.487	4.960	4.800	4.730	5.586	5.305	16.398	36.193	52.591	51	Silver
	Benjamin CHEN	5.824	10.493	5.857	2.182	3.949	2.944	4.500	3.405	2.586	4.168	16.318	29.592	45.909	84	Silver
	Guang Jun Joseph LIM	2.326	9.100	5.857	1.818	4.308	3.840	3.300	4.351	4.707	2.737	11.426	30.918	42.344	108	Bronze
	Chin Heng GAN	2.093	8.560	5.857	1.818	3.410	0.960	3.800	4.162	3.776	4.295	10.653	28.078	38.731	126	Bronze
Slovakia	Martin LUKACISIN	12.565	14.300	5.000	7.455	4.128	4.000	2.500	4.351	2.638	2.063	26.865	32.135	59.000	24	Gold
	Erik ANDRIS	12.030	16.177	5.571	1.455	4.846	5.792	3.800	3.784	2.741	0.505	28.207	28.495	56.701	35	Silver
	Boris FACKOVEC	9.535	12.950	6.571	3.636	4.128	3.520	3.800	4.919	4.397	1.389	22.485	32.361	54.846	44	Silver
	Lubica KRAUSKOVA	3.561	11.733	5.000	2.364	4.487	3.296	1.000	3.405	0.000	1.642	15.294	21.194	36.488	141	Bronze
Slovenia	Jan KOGOJ	9.488	2.467	6.143	8.000	4.487	4.576	1.000	4.351	2.534	3.663	11.955	34.755	46.710	77	Silver
	Jan BITENC	6.000	11.450	4.714	1.455	5.564	5.280	2.100	3.027	2.069	4.337	17.450	28.546	45.996	83	Silver
	Irena MATKOVIČ	2.791	3.400	6.000	6.545	4.487	5.920	1.000	2.838	0.155	2.484	6.191	29.430	35.621	147	Bronze
	Miha Emerik HABIC	2.907	6.200	5.571	1.818	3.051	2.400	1.000	3.027	0.724	2.358	9.107	19.950	29.057	188	
Spain	Victor Lopez FERRANDO	10.716	5.560	5.571	3.273	2.154	5.440	0.500	2.081	0.517	0.337	16.276	19.873	36.149	144	Bronze
	Alberto Garcia BOSQUE	2.837	8.050	5.286	1.818	1.436	3.840	1.000	5.486	0.310	1.726	10.887	20.903	31.790	174	
	Andres Suarez VELAZQUEZ	8.564	1.400	3.857	2.727	2.513	2.624	0.700	5.297	0.259	0.968	9.964	18.946	28.910	190	
	Alberto Sanchez Molero	7.720	1.833	1.143	1.818	0.718	4.800	1.000	1.892	0.000	0.968	9.554	12.339	21.893	219	

Sweden	Oscar Carl Gunnar GRANBERG	8.140	15.350	5.571	3.818	5.744	0.480	1.000	3.878	0.517	1.179	23.490	22.188	45.677	86	Silver
	Daria Ewa STRUSKA	2.326	10.900	3.857	0.727	4.308	0.480	1.000	3.027	1.345	2.316	13.226	17.060	30.285	180	
	Stella Lucie RIAD	3.209	6.450	2.429	3.455	2.154	2.976	1.000	4.162	0.724	0.968	9.659	17.868	27.527	194	
	Axel Nils Ola GOTTFRIES	5.875	4.250	5.000	0.909	2.513	3.040	0.500	1.703	0.000	1.137	10.125	14.801	24.927	205	
Switzerland	Lucia Domenica MEIER	7.442	15.200	3.571	3.091	3.590	3.200	0.700	3.595	0.000	1.895	22.642	19.641	42.283	110	Bronze
	Max HAFLIGER	5.936	0.000	6.143	2.545	4.667	1.984	1.500	3.405	5.069	3.326	5.936	28.640	34.575	151	Bronze
	Andreas FRUTIGER	7.922	10.000	4.714	0.000	2.333	3.200	1.000	1.892	0.310	1.389	17.922	14.839	32.761	162	HM
	Frederic COTTIER	1.395	6.133	5.000	0.727	2.872	1.760	1.500	2.459	0.155	0.505	7.529	14.979	22.508	217	
Tajikistan	Khursand YOROV	1.395	5.067	4.286	6.909	5.385	6.720	2.200	4.824	0.000	0.926	6.462	31.250	37.712	133	Bronze
	Umed BOLTAEV	5.581	1.000	3.286	2.364	3.410	4.960	2.000	3.595	4.914	1.095	6.581	25.623	32.204	167	HM
	Saidullo SULAYMONZODA	0.000	0.200	4.000	2.818	4.487	2.368	1.200	4.351	0.776	0.000	0.200	20.001	20.201	225	
	Khusrav OLIMI	1.395	6.300	1.286	0.364	0.718	2.176	1.200	2.649	1.086	0.000	7.695	9.478	17.174	231	
Thailand	Bavorn HONGSRICHINDA	14.186	17.950	6.143	3.636	4.128	4.832	3.200	4.351	1.190	2.021	32.136	29.501	61.638	17	Gold
	Tanatorn KHOTAVIVATTANA	4.461	11.750	6.429	5.455	5.923	3.680	2.800	5.392	5.328	5.853	16.211	40.858	57.069	33	Silver
	Pornchai KAEWSAPSAK	4.186	10.400	6.714	4.545	5.923	3.526	6.000	6.149	0.517	2.484	14.586	35.859	50.445	56	Silver
	Techin CHULADESA	9.070	3.033	5.286	4.364	4.487	5.280	3.500	5.014	2.793	2.821	12.103	33.544	45.647	87	Silver
Turkey	Hande BOYACI	18.067	8.867	4.714	4.909	5.205	3.936	2.600	4.162	2.379	5.053	26.934	32.959	59.893	21	Gold
	Ahmet Selim HAN	9.767	4.633	4.857	5.273	4.487	3.680	4.900	0.757	2.534	2.484	14.401	28.972	43.373	99	Bronze
	Dogukan DIKMEN	0.930	3.800	5.143	3.091	5.205	4.416	2.500	4.541	3.983	2.063	4.730	30.941	35.672	146	Bronze
	Mehmet VURAL	1.860	2.910	5.571	2.182	1.974	2.560	3.500	3.973	3.103	1.937	4.770	24.801	29.571	185	
Turkmenistan	Serdar ROZYYEV	1.977	15.250	5.000	1.727	1.795	5.600	2.900	2.838	2.431	1.347	17.227	23.638	40.865	116	Bronze
	Batyr Garlyyev	9.847	1.800	4.714	1.091	5.205	3.872	2.500	4.730	2.638	2.358	11.647	27.108	38.755	125	Bronze
	Muradov NURMUHAMMET	0.000	7.700	4.286	3.636	5.564	3.040	0.500	4.730	1.914	2.021	7.700	25.691	33.391	157	Bronze
	Sohbet HOJAMUHAMMEDOV	0.000	0.000	1.143	1.091	0.000	0.640	1.100	0.378	0.000	0.000	0.000	4.352	4.352	255	
Ukraine	Ostap CHERVAK	2.849	14.110	6.714	3.273	5.564	5.280	3.600	6.622	2.534	4.842	16.959	38.429	55.388	39	Silver
	Volodymyr TKACHENKO	2.698	10.333	5.286	0.364	5.564	5.280	2.500	3.595	5.948	2.316	13.031	30.852	43.883	94	Bronze
	Kirill POLISCHUK	5.018	3.100	5.714	6.727	5.923	6.176	5.200	0.000	2.690	1.937	8.118	34.367	42.485	106	Bronze
	Olha BALABON	5.426	1.500	6.143	5.818	4.487	3.456	5.000	3.973	0.931	3.663	6.926	33.471	40.398	119	Bronze

United Kingdom	Matthew James CLIFFE	9.070	5.860	5.286	6.182	5.205	4.672	3.300	6.811	1.552	5.137	14.930	38.144	53.074	50	Silver
	Frederick Robert William Meath MANNERS	7.105	10.793	6.857	8.000	4.128	4.480	1.200	3.027	5.586	1.263	17.898	34.542	52.440	53	Silver
	Derek Steven Hung-Che CHAN	4.885	5.900	6.143	7.273	5.205	5.760	1.900	4.730	0.517	2.484	10.785	34.012	44.797	91	Bronze
	Jaroslav ZAK	6.275	1.850	5.714	7.364	4.128	1.280	2.900	5.865	0.310	0.505	8.125	28.067	36.191	143	Bronze
United States	Brian Kihoon LEE	5.440	9.650	5.286	2.182	3.769	5.760	5.300	4.162	7.086	6.611	15.090	40.156	55.246	40	Silver
	Justin KOH	8.791	16.650	5.000	1.091	5.564	4.160	1.100	6.243	2.069	4.253	25.441	29.480	54.921	43	Silver
	Kenneth BREWER	2.151	12.500	5.571	7.273	6.641	3.680	1.600	5.108	0.000	4.337	14.651	34.210	48.861	65	Silver
	Sofia IZMAILOV	9.128	3.150	4.286	1.727	4.846	2.656	1.500	3.595	0.931	2.653	12.278	22.193	34.471	152	Bronze
Uruguay	Joaquin GRASSI	2.791	0.900	2.143	1.818	0.538	0.320	1.200	2.743	0.724	0.000	3.691	9.487	13.178	240	
	Sebastian BARCARDAL	2.326	0.000	2.429	0.727	0.000	0.704	1.000	1.514	0.310	0.505	2.326	7.189	9.515	245	
	Diego OTERO	2.488	0.900	0.286	0.364	0.718	1.280	0.200	1.419	0.000	0.000	3.388	4.266	7.655	249	
	Sebastian FIAMENE	2.326	0.000	0.286	0.727	0.000	1.120	1.000	0.568	0.310	0.000	2.326	4.011	6.336	250	
Venezuela	Gabriel Eduardo Sanoja LOPEZ	11.734	15.100	3.143	3.273	3.769	2.880	1.000	2.838	1.448	0.000	26.834	18.351	45.185	88	Bronze
	Daniel Enrique Cardenas ARMAS	10.465	6.850	4.571	3.273	7.000	1.408	1.300	0.946	0.000	2.189	17.315	20.688	38.003	129	Bronze
Vietnam	Minh Nguyen Thi NGOC	2.698	8.500	5.857	7.091	7.000	7.040	5.000	5.676	7.190	2.189	11.198	47.043	58.241	27	Gold
	Ha Phan Tran HONG	8.605	3.400	5.857	7.818	6.282	5.440	3.500	5.770	6.672	1.095	12.005	42.435	54.439	45	Silver
	Linh Bui LE	11.121	1.450	4.143	5.455	4.128	5.440	5.800	5.297	1.759	1.853	12.571	33.874	46.445	80	Silver
	Manh Le DINH	3.047	1.000	5.857	4.636	5.205	5.286	4.000	1.324	2.276	0.000	4.047	28.585	32.632	163	HM

Comparative Analysis of the IChO Results from 1990 to 2007

Year	Country	First Gold	Last Gold	Δ(Gold/Silver)	First Silver	Last Silver	Δ(Silver/Bronze)	First Bronze	Last Bronze	Δ(Bronze/Non-Medalists)	First Non-Medalist
1990	France	82	65	2.75	62.25	57.25	1.25	56	42.5	1.5	41
1991	Poland	94.75	87.25	1.25	86	77	0.75	76.25	61.5	1.5	60
1992	USA	96.42	90.42	0.38	90.04	85.85	0.44	85.41	78.01	0.39	77.62
1993	Italy	83.5	75.5	2.5	73	64.5	0.5	64	49.5	1.5	48
1994	Norway	83.87	79.14	0.714	78.426	72.49	0.705	71.785	58.936	0.326	58.61
1995	China	95.541	82.115	0.32	81.795	73.027	0.322	72.705	60.124	0.002	60.122
1996	Russia	92.251	79.717	1.135	78.582	67.133	0.128	67.005	53.151	0.459	52.692
1997	Canada	81.25	72.5	0.5	72	65.75	0.75	65	54.5	0.5	54
1998	Australia	95.49	88.36	0.22	88.14	80.17	0.65	79.52	65.6	0.86	64.74
1999	Thailand	94.118	81.609	1.249	80.36	70.061	0.145	69.916	53.158	0.203	52.955
2000	Denmark	94.46	80.313	0.468	79.845	71.914	0.341	71.573	58.201	0.5	57.701
2001	India	92.31	82.91	1.1	81.81	68.61	0.27	68.34	50.13	0.73	49.4
2002	Netherlands	92.5	81.35	2.23	79.12	72.14	0.3	71.84	61.45	0.51	60.94
2003	Greece	96.43	87.83	0.3	87.53	80.07	1.04	79.03	65.13	0.99	64.14
2004	Germany	88.7	72.1	1.1	71	60	0.4	59.6	47	0.9	46.1
2005	Taiwan	96.75	90.6	0.89	89.71	80.62	0.54	80.08	64.07	0.85	63.22
2006	Korea	93.43	70.61	0.48	70.13	56.71	0.32	56.39	39.41	0.17	39.24
2007	Russia	76.71	57.423	0.229	57.194	45.647	0.462	45.185	33.335	0.322	33.013

The 39th IChO Organizers acknowledge Dr. Wolfgang Hampe for the idea of the statistical analysis and contribution of the data

List of Mentors, Observers, and Guests

Country	Role	Name
Argentina	HM	Jorge Alberto Onofrio Bruno
	M	Maria Laura Uhrig
Armenia	HM	Lida Sahakyan
	M	Artak Tovmasyan
Australia	HM	Anthony Edward Phillips
	M	Alex Chit Hei Wong
	SO	Mark John Ellison
Austria	HM	Manfred Kerschbaumer
	M	Lisbeth Berner
Azerbaijan	HM	Vaqif Abbasov
	M	Mutellim Abbasov
	SO	Yusif Abdullayev
	SO	Nasim Ajdar Abishov
Belarus	HM	Viktar Khvaluk
	M	Aliaksandr Rahoisha
Belgium	HM	Sebastien Delfosse
	M	Hans L.S. Vanhoe
	SO	Cedric Pascal Patrick Malherbe
Brazil	HM	Sergio Maia Melo
	M	Jose Arimateia Dantas Lopes
	SO	Lucia Souza Carvalho Melo

Bulgaria	HM	Donka Nikolova Tasheva
	M	Penka Vasileva Tsanova
Canada	HM	Andrew Paul Dicks
	M	Stanislaw Skonieczny
China	HM	Lianyun Duan
	M	Ke-qing Zhao
	SO	Ying-xia Wang
	SO	Bi-qin Wang
Chinese Taipei	G	Tai-Shan Fang
	G	I-Hsing Chen
	HM	I-Jy Chang
	M	Bih-Yaw Jin
	SO	Tun-Cheng Chien
	SO	Ya-Ling Chen
Croatia	HM	Branka Zorc
	M	Tomislav Cvitas
Cuba	HM	Luis Enrique Guerra Cas-tano
Cyprus	HM	Anaxagoras Hadjiosif
	M	Stella Ioannou-Loucaides
Czech Repub-lic	HM	Eva Muchova
	M	Petr Slavicek
Denmark	HM	Kurt Bjoenager Nielsen
	M	Hanne Busk
	SO	Morten Foverskov
Estonia	HM	Uno Maeorg
	M	Vladislav Ivanishtshev
Finland	HM	Jorma Kullervo Koskimies
	M	Markku Rafael Sundberg
	SO	Nina Helmi Katariina Aremo

France	HM	Adrien Sebastien Meglio
	M	Guillaume Meriguet
	SO	Vincent Tejedor
Germany	HM	Sabine Ingeborg Nick
	M	Wolfgang Hampe, StD
	SO	Carsten Schmuck
Greece	HM	Anastasia Detsi
	M	Dimitrios Chiniadis
Hungary	HM	Gyorgy Tarczay
	M	Szilard Varga
	SO	Laszlo Turi
	SO	Attila Villanyi
	SO	Andras Kotschy
Iceland	HM	Gisli Holmar Johannes-son
	M	Sigurdur Vidir Smarason
	SO	Margret Lilja Bjornsdottir
India	HM	Dilip Kumar Maity
	M	Sambasivan Venkat Es-waran
	SO	Swapna Mahesh Narvekar
Indonesia	HM	Riwandi Sihombing
	M	Djulia Onggo
	SO	Ismunaryo Moenandar
Iran	HM	Mansour Abedini
	M	Ebrahim Kianmehr
	SO	Seyed Ali Seyedi Esfa-hani
	SO	Mahin Jabalameli

Ireland	HM	Paraic James
	M	Wesley Richard Browne
Israel	HM	Moris S. Eisen
	M	Iris Barzilai
Italy	HM	Mario Anastasia
	M	Pietro Allevi
Japan	HM	Yoshiyuki Sugahara
	M	Noriyuki Yonezawa
	SO	Keijiro Taga
	SO	Masatada Matsuoka
Kazakhstan	HM	Kurmangali Bekishev
	M	Rassima Sadakbayeva
Korea Republic	G	Eui seo Park
	G	Duckhwan Lee
	G	Sookyon, Yeo Lee
	HM	Jung Hag Park
	M	Tai Jong Kang
	SO	Seonghoon Lee
	SO	Hee Gweon Woo
Kuwait	M	Barak Mehdi Hadi
	M	Fotouh Alshamali
Kyrgyzstan	HM	Minira Batkibekova
	M	Raina Asakeeva
Latvia	HM	Ināra Akmene
	M	Skaidrite Pakule
Lithuania	HM	Rimantas Raudonis
	M	Edvinas Orentas

Malaysia	G	Mohd Shah Noriah
	G	Turiman Punia
	HM	Mohd Jamil Maah
	M	Noorsaadah A. Rahman
	SO	Mei Leng Lee
Mexico	HM	Carlos Mauricio Castro-Acuna
	M	Eugenio Octavio Reyes Salas
Moldova	HM	Nadejda Gheorghe Velisco
	M	Andrei Mihail Bunescu
Mongolia	HM	Dorj Daichaa
	M	Nyamgerel Choijilsuren
	SO	Davaasuren Sandag
Netherlands	HM	Peter de Groot
	M	Emiel de Kleijn
	SO	Cornelis Beers
New Zealand	HM	Suzanne Margaret Boniface
	M	David Salter
Nigeria	G	Olayemi Albert Bamikole
	G	Grace Oni Ojo
	SO	Sunday Asher Adedeji
Norway	HM	Hans-Petter Hersleth
	M	Kristian Vestli
Pakistan	HM	Khalid Mohammed Khan
	M	Muhammad Shaiq Ali

Peru	HM	Bertha Beatriz Flores Alor
	M	Galina Shevtsova
Poland	HM	Marek Orlik
	M	Janusz Stepinski
Portugal	HM	Diana Claudia Gouveia Alves Pinto
	M	Maria do Amparo Ferreira Faustino
	SO	Alzira Pinto Rebelo
Romania	HM	Marius Andruh
	M	Mihaela Maria Hillebrand
	SO	Daniela Elisabeta Bogdan
Russian Federation	HM	Sergey Igorevich Kargov
	M	Alexandr Belov
	SO	Alexey Zeifman
Saudi Arabia	G	Mohammed Abdulkarim Ibrahim
	HM	Ghanem Saad Al-Ghanem
	M	Hadi Ali Bahari
	SO	Hassan Ahmed Masslouf
Singapore	HM	Karen K.W. Mak
	M	Basheer Chanbasha
	SO	Loy Chuan Chua
Slovakia	HM	Anton Sirota
	M	Marta Salisova
	SO	Jan Reguli
Slovenia	HM	Darko Dolenc
	M	Andrej Godec

Spain	HM	Juan Antonio Rodriguez Renuncio
	M	Maria Carmen Cartagena Causape
	SO	Fernando Latre David
Sweden	HM	Per Henning Lindgren
	M	Ulf Charles Jaglid
	SO	Anna Cecilia Stenberg
Switzerland	HM	Maurice Cosandey
	M	Thomas Engeloch
Tajikistan	HM	Abdufatokh Hotamov
	M	Golibsho Takdirovich Nasymov
Thailand	G	Narongsil Thooppanom
	HM	Vudhichai Parasuk
	M	Yongsak Sritana-Anant
	SO	Amarawan Intasiri
	SO	Ekasith Somsook
Turkey	HM	Jale Hacaloglu
	M	Cihangir Tanyeli
Turkmenistan	HM	Guvanchmyrat Paytakov
	M	Aman Begliyev
Ukraine	HM	Galyna Malchenko
	M	Yuriy Kholin
United Kingdom	HM	Charles Stuart McCaw
	M	Timothy Graham Hersey
	SO	Henneli Greyling
	SO	William Peter Nolan

United States	G	Katherine Ringland Kotz
	G	Ronald Edward Monson
	HM	John Carl Kotz
	M	Kara Anne Pezzi
	SO	John Leon Kiappes
Uruguay	HM	William Stebniki
Venezuela	HM	Amalia Torrealba
	M	Eliseo Silva
Vietnam	G	Hung Pham Tuan
	G	Nga Nguyen Thi
	HM	Hue Tran thanh
	M	Hien Pham dinh
	SO	Dau Nguyen Van

IChO-2007 BUDGET

		US $
1.	**Total Budget of the IChO-2007**	**2 956 200**
1.1.	Governmental source	1 813 600
1.2.	Sponsors	1 070 000
1.3.	Participation fees	72 600
2.	**Expenditures of the IChO-2007**	**2 956 200**
2.1.	**Examination preparation**	**1 111 700**
2.1.1.	Equipment	595 500
2.1.2.	Reagents	203 200
2.1.3.	Practical and theoretical preparatory and examination tasks	65 000
2.1.4.	Facilities for the International Jury meetings and translation	248 000
2.2.	**Accomodation and Food**	**860 000**
2.2.1.	Students	380 000
2.2.2.	Mentors	480 000
2.3.	**Transportation**	**154 700**
2.3.1.	Students	98 000
2.3.2.	Mentors	56 700
2.4.	**Opening and Closing Ceremonies**	**120 000**
2.5.	**Cultural program**	**68 000**
2.5.1.	Students	44 000
2.5.2.	Mentors	24 000
2.6.	**Secretariat and operation**	**178 600**
2.6.1.	Staff costs	162 800
2.6.2.	Equipment and services	15 800
2.7.	**Guides**	**42 000**
2.8.	**Public relations**	**207 200**
2.8.1.	Catalyzer	60 000
2.8.2.	Souvenirs	81 200
2.8.3.	Presentations, mass media	66 000
2.9.	**The 39th IChO web-server**	**34 100**
2.10.	**Final report**	**16 000**
2.11.	**Consumables**	**12 300**
2.12.	**Other**	**151 600**

Participation fees for the IChO-2007

No.	Country	Amount, US $
1	Argentina	1300
2	Armenia	200
3	Australia	800
4	Austria	2000
5	Azerbaijan	800
6	Belarus	1200
7	Belgium	2000
8	Brazil	900
9	Bulgaria	2000
10	Canada	1000
11	China	1200
12	Chinese Taipei	200
13	Croatia	800
14	Cuba	1600
15	Cyprus	1800
16	Czech Republic	1500
17	Denmark	700
18	Estonia	1400
19	Finland	1900
20	France	1700
21	Germany	300
22	Greece	400
23	Hungary	2000
24	Iceland	600
25	India	600
26	Indonesia	800
27	Iran	1500
28	Ireland	1100
29	Israel	200
30	Italy	1400
31	Japan	500
32	Kazakhstan	1000
33	Korea	100
34	Kuwait	1500

35	Kyrgyzstan	800
36	Latvia	1700
37	Lithuania	1700
38	Malaysia	200
39	Mexico	1600
40	Moldova	100
41	Mongolia	200
42	Netherlands	500
43	New Zealand	1600
44	Nigeria	
45	Norway	1300
46	Pakistan	200
47	Peru	400
48	Poland	1600
49	Portugal	500
50	Romania	2000
51	Russia	0
52	Saudi Arabia	200
53	Singapore	1800
54	Slovakia	1500
55	Slovenia	1700
56	Spain	1200
57	Sweden	2000
58	Switzerland	2000
59	Tajikistan	400
60	Thailand	800
61	Turkey	1400
62	Turkmenistan	600
63	U.S.A.	1500
64	Ukraine	1400
65	United Kingdom	2000
66	Uruguay	
67	Venezuela	1500
68	Vietnam	1200
Total Amount		**72600**

Preparations

2005

January– Choose the Venue: Chemistry Department, M.V. Lomonosov Moscow State University

February – Choose the Period of the IChO

December – Participation in the International Steering Committee Meeting, Korea

2006

February – Science Committee started its work

July, 4 – Order of Prime-Minister of Russian Federation

July – visit to the 38th IChO in Yeungnam University, Korea

September – Order of Ministry of Education and Science, Russian Federation

October – Order of Rector of M.V. Lomonosov Moscow State University

October, 20 – Internet-site launched

December, 7-10 – International Steering Committee Meeting, Moscow

December – IChO 2007 Tentative Program

2007

January – Official Invitation

January – Budget Funding from State Budget

January-April – Laboratory Renovation

February, 1 – Upload Preparatory Problems on Internet

February – On-Line Registration Launched

February-June – On-Line Registration

February – Select Guides and Staff

July, 15 to 24 – IChO

December – Report to the International Steering Committee, Budapest

People who made the IChO-2007 possible

Organizing Committee [1]

Petr Anisimov (*Federal Agency for Education, RF*)

Grigorii Balykhin (*Federal Agency for Education, RF*)

Tatiana Beshenenko (*Federal Agency for Education, RF*)

Nikolai Bulaev (*State Duma, RF*)

Evgenii Butko (*Federal Agency for Education, RF*)

Svetlana Demidova (*Federal Agency for Education, RF*)

Vadim Eremin

Elena Eremina

Andrei Fursenko – Chairman, Minister of Education and Science, RF

Alexander Gladilin

Isaak Kalina (*Ministry of Education and Science, RF*)

Lyudmila Kokhanova

Nikolai Kuz'menko

Valerii Lunin – President of the IChO-2007

Vladimir Mironov (*Vice-Rector, MSU*)

Elena Pazyuk

Victor Shtepa

Lyubov' Strel'nikova (*Chief Editor, Khimiya I Zhizn'*)

Vladimir Terenin

Science Committee

Ivan Babkin	Anna Bacheva
Yurii Barbalat	Mikhail Beklemishev
Svetlana Bendrysheva	Anna Berkovitch
Zhanna Boeva	Alexander Bogachev
Andrei Cheprakov	Vadim Eremin, Co-Chair
Bulat Garifullin (*Bashkirian Medical State University*)	Andrei Garmash
Alexander Gladilin, Co-Chair	Il'ya Glebov
Eugene Karpushkin	Alexander Kisin (*Institute of Chemistry and Technology of Organoelement Compounds*)

[1] Affiliation by default: Chemistry Department of MSU

Mikhail Korobov
Alexey Korovin
Sergei Legotskii
Nikolay Melik-Nubarov
Kirill Oskolok
Nina Pasekova
Valery Putlyaev
Marina Reshetova
Marina Rozova
Igor Sedov (*Kazan' State University, A.Butlerov Institute of Chemistry*)
Irina Seregina
Sergey Seryakov
Mikhail Statkus
Boris Tarasevich
Igor Trushkov
Igor Tyulkov
Julia Valeeva
Andrei Vedernikov (*Univ. of Maryland*)

Secretariat

Anna Bacheva
Anna Berkovich
Anastasiya Chekanova
Elena Eremina
Elena Pazyuk
Boris Pokrovskii (*web*)
Mikhail Tabunov (*web*)
Ekaterina Yakubovich

Technical Committee

M. Belyakov
A. Bibin
M. Chudakova
A. Demidova
A. Ezhov
M. Galkin
An. Gladilin
D. Ivanov
K. Ivanova
P. Kebets
A. Marinchuk
A. Natikan
M. Nikitina
A. Poteryaev
E. Rodina
M. Steklov
V. Valaeva
S. Vatsadze
A. Veresov

Lab instructors

N. Aryutkina
P. Binevskiy
P.Chelushkin
A. Chemagin
M. Chernobrovkin
G. Dudina
O. Fedyanina
V. Figurovskaya
E. Ivanainen
S. Ivanova
S. Kurzeev
M. Livantsov
L. Livantsova
I. Men'shikova
I. Naperova
O. Popova
V. Sergeeva
I. Shender
O. Starostina
T. Suslenkova
G. Ushakov
S. Vatsadze
Yu. Volkova
I. Zorov

Lab assistants

G. Demchuk	A. Druzhinina	D. Dzhigailo
T. Klimashina	N. Krutova	S. Kubyshev
P. Kudan	L. Lukanina	O. Lukanina
T. Lyskova	S. Matusova	T. Matyushina
E. Mishukova	O. Monogarova	N. Potapova
L. Sergeeva	L. Shadskaya	L. Shimko
M. Tereshina	K. Yablotskiy	A. Zatirakha

Spectrophotometer operators

O. Anikina	O. Bogomolova	V. Bugrin
D. Davydov	A. Filatov	L. Filatova
E. Gerasimova	A. Gopin	N. Gruzinskaya
A. Kislukhin	M. Kondrashov	N. Kovaleva
D. Maltseva	M. Nemykh	D. Pavlov
I. Protasov	E. Sbrueva	T. Semashko
V. Skorkin	Yu. Smirnova	M. Smolov
A. Sokolyuk	V. Spiridonov	S. Uglanova
V. Vasil'yev	A. Zhirnov	

"Catalyzer" team

A. Agaeva	E. Bredina	K. Davydova
M. Eremina	A. Galieva	M. Kokhanova
A. Kravtsova	A. Lobus (photo)	A. Lukichev (head)
I. Lukichev	M. Nefedieva	A. Pomerantseva
I. Salynkina	S.Sobolev	V. Turin

Opening and Closing Ceremonies designed by Victor Shiryaev

Doctors – Olga Eremina and Tatiana Pogorelova

Guides

Argentina	Anna Kovrigina
Armenia	David Ayrapetyan
Australia	Nadezhda Kolesnik
Austria	Daniil Zaonegin
Azerbaijan	Eldar Rizaev
Belarus	Vitaliy Sushkevich
Belgium	Alexey Rozov
Brazil	Kate Abramova
Bulgaria	Georgi Valeriev Stoychev
Canada	Artem Kovalenko
China P.R.	Jin Zhao
Chinese Taipei	Anna Lyamina
Croatia	Anastasiya Galanina
Cuba	Anna Kalyushnaya
Cyprus	Elena Ivanova
Czech Republic	Kate Zaharevich
Denmark	Nadezhda Ogneva
Estonia	Eugenia Tamyar
Finland	Alexey Shikhantsov
France	Etienne Richard
Germany	Zhenya Kazanova
Greece	Anton Tunin
Hungary	Alexei Kulagin
Iceland	Svetlana Khoronenkova
India	Sergey Kovalevskiy
Indonesia	Marina Frolova
Iran	Tatiana Kononova
Ireland	Maxim Abakumov
Israel	Ksenia Sarycheva
Italy	Marina Ulanovskaya
Japan	Maria Khrenova
Kazakhstan	Timur Zhiyentayev
Korea Republic	Natalia Leshakova
Kyrgyzstan	Artem Skabeev
Latvia	Maxim Homutov
Lithuania	Dasha Yovcheva

Malaysia	Alexandra Malishkina
Mexico	Nina Kozhemyakina
Moldova	Andrey Istrate
Mongolia	Ganbaatar Tsetserleg
Netherlands	Elena Galysheva
New Zealand	Kate Yakubovich
Norway	Natalia Morukova
Pakistan	Alexander Kuznetsov
Peru	Lidia Bogatyreva
Poland	Evgeniya Zhukovskaya
Portugal	Valentina Pyatickh
Romania	Alexey Godina
Russian Federation	Oleg Chernov
Saudi Arabia	Samir Zheltisov
Singapore	Mila Shtepa
Slovakia	Yana Kresan
Slovenia	Maria Kuleshova
Spain	Olga Usovich
Sweden	Kate Zakharevich
Switzerland	Daniil Troshinkin
Tajikistan	Ulmas Zhumaev
Thailand	Diana Kfuri
Turkey	Kyiyalbek Kaparov
Turkmenistan	Anton Reshetnyak
Ukraine	Maxim Zabilskiy
United Kingdom	Mikhail Sheybe
United States	Daria Tsareva
Uruguay	Azalia Korunbaeva
Venezuela	Anastasiya Nevokshanova
Vietnam	Nguen Din Tyyong
mentors	Anna Dyachenko
mentors	Alexandr Veresov
mentors	Igor Tyulkov
mentors	Oleg Brilev
guests	Aleksandra Prokhorova