Analysis of the experimental part of the IChO competition

According to the regulations of the IChO the organizer must guarantee equal conditions for each participant. No wonder that this a critical and deciding point of the organization of the IChO. As long as the number of participating countries and thus, the number of competitors was small (for example, 48 competing pupils took part in the 10th IChO in 1978), the authors were not forced too much to account with room possibilities. The next table shows the increase of the number of the participants during the years.

Year	Number o participants
1968	**18**
1980	**more than 50**
1987	**more than 100**
1993	**more than 150**
2000	**more than 200**
2006	**more than 250**
2018	**more than 300**

It is easy to imagine how many problems can arise for the organizer at present when experimental tasks are prepared for the competition. Several laboratories, many facilities and chemicals are needed and, naturally, the competition becomes demanding from the financial point of view as well. Those are the limiting factors for a choice of experimental problems. Under these circumstances it is no wonder that the types of experimental problems are repeated to a certain extent and the problems can be divided according to their contents into certain groups as it is shown and summarized in Table 1.

Table 1: **The types and numbers of experimental problems set in particular IChOs**

IChO	Country Code	City	Year	Total Number of tasks	The types and numbers of experimental IChO problems *)				
					I	**II**	**III**	**IV**	**V**
1st	CS	Prague	1968	**2**	**2**	**-**	**-**	**-**	**-**
2nd	PL	Katowice	1969	**2**	**1**	**-**	**-**	**-**	**1**
3rd	H	Budapest	1970	**2**	**1**	**-**	**1** $_{A}$	**-**	**-**
4th	SU	Moscow	1972	**2**	**1**	**-**	**1** $_{A,B}$	**-**	**-**
5th	BG	Sofia	1973	**3**	**2**	**1**	**-**	**-**	**-**

6th	RO	Bucurest	1974	**3**	**2**	**1**	**-**	**-**	**-**
7th	H	Veszprem	1975	**4**	**2**	**1**	**1 A**	**-**	**-**
8th	DDR	Halle	1976	**3**	**1**	**1**	**1 A,B**	**-**	**-**
9th	CS	Bratislava	1977	**3**	**-**	**-**	**1 A**	**-**	**2**
10th	PL	Torun	1978	**2**	**-**	**-**	**1 A**	**-**	**1**
11th	SU	Leningrad	1979	**2**	**1**	**-**	**1 B**	**-**	**-**
12th	A	Linz	1980	**3**	**1**	**1**	**1 B**	**-**	**-**
13th	BG	Burgas	1981	**3**	**1**	**1**	**1 A**	**-**	**-**
14th	S	Stockholm	1982	**3**	**1**	**-**	**1A +1E**	**-**	**-**
15th	RO	Timisoara	1983	**2**	**-**	**1**	**1 B**	**-**	**-**
16th	D	Frankfurt	1984	**2**	**-**	**-**	**1 A**	**1 G**	**-**
17th	CS	Bratislava	1985	**1**	**-**	**1 A**	**-**	**-**	**-**
18th	NL	Leiden	1986	**2**	**-**	**-**	**1 A,D,E**	**1 F**	**-**
19th	H	Veszprem	1987	**3**	**1**	**-**	**1 C**	**-**	**3**
20th	SF	Espoo	1988	**2**	**-**	**-**	**-**	**1 G**	**1**
21st	DDR	Halle	1989	**2**	**-**	**-**	**1 A**	**1 G**	**-**
22nd	F	Paris	1990	**4**	**1**	**-**	**1 C**	**1 G**	**1**
23th	PL	Lodz	1991	**2**	**-**	**-**	**1 A**	**-**	**1**
24th	USA	Pittsburgh	1992	**1**	**-**	**-**	**1 E**	**-**	**-**
25th	I	Perugia	1993	**2**	**-**	**-**	**1 A**	**1 G**	**-**
26th	N	Oslo	1994	**1**	**-**	**-**	**1 A,E**	**-**	**-**
27th	CHINA	Beijing	1995	**3**	**1**	**-**	**1 E**	**1 F**	**-**
28th	RUS	Moscow	1996	**2**	**-**	**-**	**1 E**	**1 G**	**-**
29th	CAN	Montreal	1997	**3**	**-**	**1**	**1 E**	**1 G**	**-**
30th	AUS	Melbourne	1998	**2**	**-**	**-**	**1 B**	**-**	**1 G,A**
31st	THAI	Bangkok	1999	**2**	**-**	**-**	**1 A**	**1 G**	**-**
22nd	DK	Copenhagen	2000	**2**	**-**	**-**	**-**	**1 B,C + 1 G**	**-**
33th	IND	Mumbai	2001	**3**	**-**	**-**	**1 G**	**1 E**	**1**
34th	NL	Groningen	2002	**3**	**-**	**-**	**-**	**-**	**3**
35th	GR	Athen	2003	**1**	**-**	**-**	**-**	**1 G**	**-**
36th	D	Kiel	2004	**2**	**1**	**-**	**-**	**1 G**	**-**
37th	TAI	Taipei	2005	**2**	**1**	**-**	**-**	**1 G**	**-**

38th	KOR	Gyeongsan	2006	**3**	**-**	**1**	**1** $_{A}$	**-**	**1**
39th	RUS	Moscow	2007	**2**	**-**	**-**	**1** $_{A}$	**-**	**1**
40th	H	Budapest	2008	**3**	**1**	**-**	**-**	**1** $_{G}$	**1**
41st	GB	Cambridge	2009	**3**	**-**	**-**	**1** $_{E}$	**1** $_{G}$	**1**
42nd	JAP	Tokyo	2010	**3**	**-**	**-**	**-**	**-**	**3**
43th	TUR	Ankara	2011	**3**	**-**	**-**	**1** $_{D,E}$	**1** $_{G}$	**1**
44th	USA	Washington	2012	**2**	**-**	**-**	**-**	**1**	**1**
45th	RUS	Moscow	2013	**3**	**-**	**-**	**1** $_{A,E}$	**1** $_{G}$	**1**
46th	VIE	Hanoi	2014	**3**	**-**	**-**	**1** $_{B,E}$	**-**	**2**
47th	AZER	Baku	2015	**3**	**-**	**-**	**1** $_{B}$	**1** $_{G}$	**1**
48th	GEOR	Tbilisi	2016	**3**	**2**	**-**	**1** $_{D}$	**-**	**-**
49th	THAI	Nakhon Pathom	2017	**3**	**-**	**-**	**1** $_{C}$	**-**	**2**
50th	SVK CZ	Bratislava, Prague	2018	**3**	**-**	**-**	**-**	**1** $_{F}$	**2**

***)**

I - Qualitative analysis of inorganic substances

II - Qualitative analysis of organic substances

III - Quantitative analysis, Volumetric determination:

A - Acidimetry, Alkalimetry; **B** - Manganometry; **C** - Iodometry;

D - Argentometry; **E** - Complexometry.

IV - Synthesis:

F- Inorganic substance; **G** - organic substance.

V - Problems of other type.

One hundred and twenty-three (123) experimental IChO problems have been set altogether in the first fifty International Chemistry Olympiads, from which 24 tasks were of Type I (it represents 19.5 %), 15 tasks of Type II (12.2 %), and 36 tasks were of Type III (29.3 %). It represents altogether 60.1 % of all experimental tasks. By the way the number of the tasks from the analytical chemistry in the first thirty IChOs was higher and the tasks of this kind represented 74.6 % (roughly ¾) of all experimental problems.

The experimental tasks from the field of analytical chemistry can be divided into three groups represented by problems from:

i) qualitative analysis of inorganic compounds (Type I),
ii) qualitative analysis of organic compounds (Type II)
iii) quantitative analysis of inorganic compounds (Type III)

The experimental analytical IChO-problems of the Type I were mostly composed as follows: Some salts, solutions or metals were available in numbered

test-tubes. It was required to prove the content in each of it. Naturally, reactions of all kinds (acid-basic, redox, precipitation, complex formation) were supposed to be used and interpreted.

Similarly, the experimental tasks of Type II (analysis of organic compounds) required the knowledge of many chemical reactions of organic compounds and especially of those of functional groups.

The qualitative analytical tasks (I and II) were preferred in the first years of the competition. Later they nearly disappeared and were set in the next IChOs only sporadically. The Table 1 shows that the problems from quantitative analytical chemistry (Type III) are most frequently set in the experimental part of the competition. It is no wonder that volumetric determinations in various modifications occurred most often (except of three in all IChOs) since there were not so many problems with appropriate facilities (burettes, pipettes, volumetric flasks etc.). However, there arises another problem connected with an effort of the authors to find new ideas for the experiments and find such volumetric determinations or combinations of determinations which would differ (at least slightly) from those set in the previous IChOs and overstep the framework of a common standard. It is accepted with sympathy and appreciated very much by the members of the International Jury if the author has succeeded in a combination of analytical or syntheses procedures with a good idea provoking the competitors to show their initiative and creativity. On the other hand, there is also a danger that the author, wanting not to be a plagiarist, involves into a competition experimental problem some indirect methods of structure determination (spectral measurements, chromatography, etc.) which are far from the requirements of secondary schools. The study of experimental problems of the previous IChOs shows that sometimes very simple tasks, however with a hidden "spark", can differentiate the competing pupils much more effectively than those which seem to be very nice at the first sight but are "oversophisticated". Since the IChO is not a competition of the authors but the pupils, it is difficult to declare in advance that a certain task is better than the other one, without having taken into consideration the results of the competition and the fact how the task proved to be a good tool for picking out of those pupils who are indeed very good in the experimental chemistry.

Table 1 shows that with regard to the experimental part of the competition we can distinguish some periods in the history of the IChOs. There were two experimental problems in the first years of the competition. Later, after the ratio of the experimental part on the total amount of points had increased, the number of experimental problems increased as well and the problems became more complicated. As if the authors would think that 40 points for two experimental tasks are too much in comparison with 60 points for theoretical tasks. This tendency was obvious from the 5th to 14th IChO. The competition contained three and even four (1975) experimental problems. In the years 1978 and 1979 two experimental problems were set only, one of these was, however, a complex task containing two consecutive experimental problems.

After 1982 the International Jury appealed to the authors to innovate the content of the experimental problems. It was emphasized that not the number but the content of the tasks are deciding for differentiation of experimental abilities of competing students. It was recommended to set in the competition at least two problems from which one should be a complex problem. As shown in Table 1 the authors accepted this challenge and the innovation of the content began already in Frankfurt (16th IChO). A simple synthesis of an organic compound combined with

melting point measuring and thin layer chromatography, was the subject of the second experimental problem.

The Table 1 shows that organic syntheses (Type IV) occurred in the tasks more and more frequently. However, the syntheses were limited by chemicals, apparatus and in particular by time. Only such compounds could be prepared which could be obtained in the form of solid products in a relatively simple way and in a sufficiently short time. The latter could be purified and dried in a simple way and some of them investigated by other relatively simple methods (for example by thin layer chromatography or spectral measurements).

The organic syntheses are accompanied with some problems and require some experience. Sometimes common written procedures are sufficient for an experienced experimenter but not for a secondary school pupil. There were similar problems in the past. In an effort to face the unforeseen situations, some organizers gave a very detailed description of a procedure. On the one hand it seemed to be useful, on the other hand, however, the procedure was too extended and it required three and more pages. Finally, it created a stress situation for the competing pupils and proved to affect the results of the pupils negatively. One must take into account that the situation in a laboratory at school is substantially different from that at the competition. The teacher in school laboratory can give an advice to the pupils, can draw their attention to important phases of the synthesis. In the IChO laboratory the supervisor cannot help the pupils and they must rely on themselves only.

The time is a limiting factor and influences the results in the experimental part to a great extent. It plays a very important role especially in the case when more experimental problems are to be solved and the author assumes that the tasks should be solved simultaneously. For example, a reaction mixture is heated under reflux for some time (Task 1) and at the same time a pupil is expected to make some other experiments in the Task 2. This may be, however, a wish of the author but the majority of pupils solve the tasks one after another. Firstly, they did not get used to such an experimental work and secondly, they are afraid of forgetting some details. As it is known the experimental problems contain some additional questions and tasks and, moreover, as it became usual in the IChOs, the answers and results must be written in appropriate windows of an answer sheet.

As it has already been mentioned there is always a danger that the author of an experimental problem does not avoid a certain stereotype. It must be appreciated therefore, if the author can find any compromise between a classic form of an experimental task and an original form of the problem which is sometimes unexpected in the IChOs and can be performed with difficulties only. Several attempts in the past can be marked as successful. The tasks of this type are in the Table 1 given in the column V.

There were two tasks of this kind set in the 9th IChO in Bratislava. In the first experimental task the competitors determined the content of hypochlorite in the solution by the thermometric titration. The pupils were requested to draw a titration curve, to determine the equivalent point and to suggest the procedure for a calculation of reaction heat. In the second task the pupil had to investigate the rate of the reaction between formic acid and bromine by visual colorimetry.

The determination of the rate of the reaction between iodide and peroxodisulphate anions was the subject of the task at the 10th IChO in Torun. The kinetic of a chemical reaction was studied in the competition experimental tasks at the 22nd IChO in Paris.

The above mentioned stereotype was also disturbed at the 20th IChO in Finland. In one experimental task the competitors had to determine spectrophotometrically the values of concentrations and those of dissociation constants of a certain weak acid. The pupils prepared solutions with a requested composition according to a given procedure, the solutions were given to servicemen to measure their absorption spectra and those were finally evaluated by pupils. The evaluation enabled to answer the required partial tasks and questions.

The experimental problem set in the 23rd IChO in Lodz was also interesting and unique. Electrochemical method was used for the determination of stability constants for ammine complexes of copper(II) and zinc(II).

The International Workshop on the Development of the International Chemistry Olympiads was organized in Amsterdam in 1990. According to the decision of the delegation leaders of 8 countries the best experimental problems in the years 1980 – 1990 were the as follows: (i) Synthesis and analysis of a nickel complex (18th IChO), (ii) Potentiometric determination of phosphoric acid in Coca-Cola (16th IChO), (iii) Preparation of a buffer solution (14th IChO), (iv) Synthesis of aspirin (21st IChO).

30 or 40 % of the total points?

In the first years of the IChO competition many discussions about the proportion of the theoretical and experimental parts of the competition took place. At first the majority of the members of the International Jury found the 30 % of the total points to be sufficient for the experimental part. Later it was desirable to increase this ratio up to 40 %. The main reason for this decision was that several theoretical questions and tasks were included by the authors in the experimental problems and thus, the share of the theory was artificially increased on the account of the experiment. Some experimental problems were changed to a certain degree into theoretical ones. Such tendency was ill.

The International Jury made many attempts in the past to face this situation and the authors were advised not to accompany the main experimental problems with some additional theoretical ones. The recommendations could be understood as a good advice but it was difficult to take any measures and give any orders to the authors. Moreover, it is not an easy task to prepare the experimental part of the competition on such a level that it would be a full-value partner of the theoretical part. However, this argument cannot serve as an excuse. It was inevitable in the past and it is also at present to face the above tendencies.

Structure of experimental problems set in the IChOs

The experimental problems set in the IChO competitions till now can be divided according to their structure into two groups:

a) Results were obtained by experiments or measurements directly and were required to be interpreted. All such tasks were from the field of qualitative analysis (inorganic or organic).
b) The values or data gained in experiments or measurements were necessary for further experiments or calculations and thus the required results could be obtained and interpreted. The problems of this type were those marked in Table 1 as III, IV, and V.

The authors and competing pupils enter a mutual dialog and they communicate via the IChO problems. Most strikingly it is shown in the experimental part of the IChO competition. In regard to the character of the experimental IChO problems the relation between the author and a competing pupil may be a relation of:

i) a full dependence,
ii) a half-dependence (or a half-independence),
iii) an independence.

The kind of the relation is first of all manifested by the manner how the experimental tasks are constructed.

i) In the first case, the pupil gets a precise instruction how to perform an experiment without having any possibility to influence the experiment. The experiment can only be carried out more or less precisely. The evaluation of the experiment depends on the precision of the experimental work but also on accidental circumstances and unforeseen aspects.

ii) In the second case, a description of an experiment is given in the main features only but the exact instruction is, as a matter of fact, not attached and the details of the experiment are expected to be proposed by the pupil.

iii) In the third case, the problem to be solved is described and the pupil has the possibility to choose the procedure of the experiment, naturally in the framework of given possibilities and conditions (facilities and chemicals available in the laboratory).

The most of the experimental problems set in the IChOs till now were of such a kind described in parts i) and ii).

Calculations in experimental problems in the IChOs

Calculations required in experimental tasks can be divided into three categories:

1. simple calculations which can be done in one or two steps,
2. calculations containing two steps at least and moreover, some other aspects are taken into account,
3. more complicated calculations including the work with diagrams, tables, etc., in which the pupils can propose their own procedure.

Results can be required in a simple way, for instance as one value obtained by measurements or gained by calculations.

Another type of the experimental task requires results in a more synthetic form. The solution includes some theoretical answers directly connected with the central problem. In some cases results are required in Tables.

Evaluation of experimental problems in the IChOs

Not only content of the experimental problems but also their evaluations were the subject of hectic discussions of the International Jury. In the first years of the competition there were efforts to evaluate both the results achieved by the competitors, and the way how the experimental results were obtained. A sophisticated system was proposed for evaluation of the quality of the competitors' experimental work. Mistakes made by the competitors in their laboratory work have as their consequence that the total number of points gained for the results in the experimental part of the competition was reduced according to an elaborated scheme. The system was brought to perfection at the 9th IChO in 1977.

Although the criteria were defined clearly certain doubts arose due to the fact that the referees were the teachers from the organizing country. The attempts to create an international team of referees failed. Later, the International Jury came to the conclusion that the evaluation of the quality of laboratory work is not necessary since it is projected onto final experimental results of the pupils. Step by step this problem was forgotten. By the way, any discussions of this kind would have no sense since the above mentioned evaluation would be impossible at the present number of participants in the IChOs.

From the historical point of view it is necessary to say that discussions on the evaluation of the experimental tasks divided the members of the International Jury into two camps. The people of the first group were of the opinion that the experimental results were the only deciding factor for the evaluation of the experimental problems and the way how the results were obtained was not interesting. They suggested not to evaluate the intermediate results (for example consumptions at the titrations) and not to check calculations since, they meant, any error had to influence the final results.

The mentors belonging to the second group were less radical. They reminded that the IChO is a competition of pupils and not a competition of laboratory technicians. The pupils are not experienced and their stay in chemical laboratories can be reckoned in hours or days and not in weeks and months. Moreover, the technician has the possibility to repeat the experiment and correct any mistake. The competing pupils cannot do that. Therefore, the mentor/author when evaluating the pupil's solution should inquire the border between still correct and already not correct procedure in the experiment or calculation.

If somebody only once entered the process of the evaluation of the pupils' solutions, he/she had to realize that it was not an easy task. The evaluation must be correct and quick. Time and again time is the limiting factor. One can object that this cannot be an important argument from didactic point of view. However, the Regulations of the IChO reflect the present situation and should be obeyed by all participants.

Compiled and edited by A. Sirota
(IChO Intern. Information Centre)