APPENDIX C

SYLLABUS OF THE INTERNATIONAL CHEMISTRY OLYMPIAD

Level 1: These topics are included in the overwhelming majority of secondary school chemistry programs and need not to be mentioned in the preparatory problems.

Level 2: These topics are included in a substantial number of secondary school programs and maybe used without exemplification in the preparatory problems.

Level 3: These topics are not included in the majority of secondary school programs and can only be used in the competition if examples are given in the preparatory problems.

1 INORGANIC CHEMISTRY

1. 1 Electronic configuration of atoms and ions

1.1.1	main groups	1
1.1.2	transition metals	2
1.1.3	lanthanide and actinide metals	3
1.1.4	Pauli exclusion principle	1
1.1.5	Hund's rule	1

1.2 Trends in the periodic table (main groups)

1.2.1	electronegativity	1
1.2.2	electron affinity	2
1.2.3	first ionization energy	2
1.2.4	atomic size	1
1.2.5	ionic size	2
1.2.6	highest oxidation number	1

1.3 Trends in physical properties (main groups)

1.3.1	melting point	1
1.3.2	boiling point	1
1.3.3	metal character	1
1.3.4	magnetic properties	2
1.3.5	thermal properties	3
1.3.6	law of Dulong and Petit	1
1.3.7	electrical conductivity	3

1.4 Structures

1.4.1	simple molecular structures	2
1.4.2	simple molecular structures with central atom exceeding octet rule	3
1.4.3	ionic crystal structures	3
1.4.4	metal structures	3
1.4.5	stereochemistry	3

1.5 Nomenclature

1.5.1	oxidation number	1
1.5.2	main group compounds	1
1.5.3	transition metal compounds	1
1.5.4	simple metal complexes	2
1.5.5	multicenter metal complexes	3

1.6 Chemical calculations

1.6.1	balancing equations	1
1.6.2	stoichiometric calculations	1
1.6.3	mass and volume relations	1
1.6.4	empirical formula	1
1.6.5	Avogadro's number	1
1.6.6	concentration calculations	1

1.7 Isotopes

1.7.1	counting of nucleons	1
1.7.2	radioactive decay	1
1.7.3	nuclear reactions (alpha, beta, gamma, neutrino) .	2

1.8 Natural cycles

1.8.1	nitrogen .	2
1.8.2	oxygen	2
1.8.3	carbon	2

1.9 s-Block

1.9.1	**Products of reactions of group I and II metals**	
1.9.1.1	with water, basicity of the products	1
1.9.1.2	with halogens	1
1.9.1.3	with oxygen	2
1.9.2	heavier s-block elements are more reactive	1
1.9.3	lithium combines with H_2 and N_2 forming LiH and Li_3N	2

1.10 p-Block

1.10.1	stoichiometry of simplest non-metal hydrides	1
1.10.2	properties of metal hydrides	3
1.10.3	acid-base properties of CH_4, NH_3, H_2O, H_2S, and hydrogen halides HX	1
1.10.4	NO reacts with O_2 to form NO_2,	1
1.10.5	equilibrium between NO_2 and N_2O_4	1
1.10.6	products of reaction of NO_2 with water	1
1.10.7	HNO_2 and its salts are reductants 1	

1.10.8	HNO_3 and its salts are oxidants	1
1.10.9	N_2H_4 is a liquid and reductant	3
1.10.10	there exist acids like $H_2N_2O_2$, HN_3	3
1.10.11	reactions of HNO_3 with different metals and reductants	3
1.10.12	reaction of $Na_2S_2O_3$ with iodine	2
1.10.13	other thioacids, polyacids, peroxoacids	3
1.10.14	B(III), Al(III), Si(IV), P(V), S(IV), S(VI), O(-II), F(-I), Cl(-I), Cl(I), Cl(III), Cl(V), Cl(VII) are normal oxidation states of 2nd and 3rd row elements in compounds with halogens and in oxoanions	1
1.10.15	compounds of non-metals with other oxidation states	3
1.10.16	the preferred oxidation states are Sn(II), Pb(II) and Bi(III)	2
1.10.17	products of reactions of non-metal oxides with water and stoichiometry of resulting acids	1
1.10.18	reactions of halogens with water	2
1.10.19	reactivity and oxidizing power of halogens decrease from F_2 to I_2	1
1.10.20	differences of chemistry between row 4 and row 3 elements	3

1.11 d-Block

1.11.1	common oxidation states of the common d-block metals are Cr(III), Cr(VI), Mn(II), Mn(IV), Mn(VII), Fe(II), Fe(III), Co(II), Ni(II), Cu(I), Cu(II), Ag(I), Zn(II), Hg(I), and Hg(II)	1
1.11.2	colours of the listed common ions in aqueous solutions	2
1.11.3	other oxidation states and chemistry of other d-block elements	3
1.11.4	Cr, Mn, Fe, Co, Ni, Zn dissolve in dilute HCl; Cu, Ag, Hg do not dissolve	1
1.11.5	products of dissolution are (2+) cations	2
1.11.6	passivation of Cr, Fe (and also Al)	2
1.11.7	$Cr(OH)_3$ and $Zn(OH)_2$ are amphoteric, other common hydroxides are not	1
1.11.8	MnO_4^-, CrO_4^{2-}, $Cr_2O_7^{2-}$ are strong oxidants	1
1.11.9	products of reduction of MnO_4^- depending on pH	2
1.11.10	polyaions other than $Cr_2O_7^{2-}$	3

1.12 Other inorganic problems

1.12.1	industrial production of H_2SO_4, NH_3, Na_2CO_3, Na, Cl_2, NaOH,	1
1.12.2	chemistry of lanthanides and actinides	3
1.12.3	chemistry of noble gases	3

2. PHYSICAL CHEMISTRY

2.1 Chemical equilibria

2.1.1	dynamical model of chemical equilibrium	1
2.1.2	chemical equilibria expressed in terms of relative concentrations	1
2.1.3	chemical equilibria expressed in terms of partial pressures	2
2.1.4	the relationship between equilibrium constants for ideal gases expressed in different ways (concentration, pressure, mole fraction)	3
2.1.5	relation of equilibrium constant and standard Gibbs energy	3

2.2 Ionic equilibria

2.2.1	Arrhenius theory of acids and bases	1
2.2.2	Broensted-Lowry theory, conjugated acids and bases	1

2.2.3	definition of pH	1
2.2.4	ionic product of water	1
2.2.5	relation between K_a and K_b for conjugated acids and bases	1
2.2.6	hydrolysis of salts	1
2.2.7	solubility product - definition	1
2.2.8	calculation of solubility (in water) from solubility product	1
2.2.9	calculation of pH for weak acid from K_a	1
2.2.10	calculation of pH for 10^{-7} mol dm^{-3} HCl solution	2
2.2.11	calculation of pH for multiprotic acids	2
2.2.12	calculation of pH for weak acid mixtures	3
2.2.13	definition of activity coefficient	2
2.2.14	definition of ionic strength	3
2.2.15	Debye-Hückel formula	3

2.3 Electrode equilibria

2.3.1	electromotive force (definition)	1
2.3.2	first kind electrodes	1
2.3.3	standard electrode potential	1
2.3.4	Nernst equation	2
2.3.5	second kind electrodes	2
2.3.6	relation between ΔG and electromotive force	3

2.4 Kinetics of homogeneous reactions

2.4.1	factors influencing reaction rate	1
2.4.2	rate equation	1
2.4.3	rate constant	1
2.4.4	order of reactions	2
2.4.5	1st order reactions: time dependence of concentration	2
2.4.6	1st order reactions: half life	2
2.4.7	1st order reactions: relation between half-life and rate constant	2
2.4.8	rate-determining step	2
2.4.9	molecularity	2
2.4.10	Arrhenius equation, activation energy (definition)	2
2.4.11	calculation of rate constant for 1st order reaction	2
2.4.12	calculation of rate constant for second, third order reaction	3
2.4.13	calculation of activation energy from experimental data	3
2.4.14	basic concepts of collision theory	3
2.4.15	basic concepts of transition state theory	3
2.4.16	opposing, parallel and consecutive reactions	3

2.5 Thermodynamics (First law)

2.5.1	system and its surroundings	2
2.5.2	energy, heat and work	2
2.5.3	relation between enthalpy and energy	2
2.5.4	heat capacity - definition	2
2.5.5	difference between C_p and C_v (ideal gas only)	2
2.5.6	Hess law	2
2.5.7	Born-Haber cycle for ionic compounds	3
2.5.8	lattice energies - approximate calculations (e.g. Kapustinski equation)	3
2.5.9	use of standard formation enthalpies	2
2.5.10	heats of solution and solvation	2

2.5.11	bond energies - definition and uses	2

2.6 Thermodynamics (Second law)

2.6.1	entropy, definition (q/T)	2
2.6.2	entropy and disorder	2
2.6.3	relation $S = k \ln W$	3
2.6.4	relation $\Delta G = \Delta H - T\Delta S$	2
2.6.5	ΔG and directionality of changes	2

2.7 Phase systems

2.7.1	ideal gas law	1
2.7.2	van der Waals gas law	3
2.7.3	definition of partial pressure	1
2.7.4	temperature dependence of the vapour pressure of liquid	2
2.7.5	Clausius-Clapeyron equation	3
2.7.6	reading phase diagrams: triple point	3
2.7.7	phase diagrams: critical temperature	3
2.7.8	liquid-vapour system (diagram)	3
2.7.9	liquid-vapour: ideal and non-ideal systems	3
2.7.10	liquid-vapour: use in fractional distillation	3
2.7.11	Henry's law	2
2.7.12	Raoult's law	2
2.7.13	deviations from Raoult's law	3
2.7.14	boiling point elevation law	2
2.7.15	freezing point depression, determination of molar mass	2
2.7.16	osmotic pressure	2
2.7.17	partition coefficient	3
2.7.18	solvent extraction	3
2.7.19	basic principles of chromatography	2

3. ORGANIC CHEMISTRY

3.1 Alkanes

3.1.1	isomers of butane	1
3.1.2	naming (IUPAC)	1
3.1.3	trends in physical properties	1
3.1.4	**substitution (e.g. with Cl_2)**	
3.1.4.1	products	1
3.1.4.2	free radicals	2
3.1.4.3	initiation/termination of the chain reaction	2

3.2 Cycloalkanes

3.2.1	names	1
3.2.2	strain in small rings	2
3.2.3	chair/boat conformation	2

3.3 Alkenes

3.3.1	planarity		1
3.3.2	E/Z (cis-trans) isomerism		1
3.3.3	**Addition of Br_2 and HBr**		
3.3.3.1	products		1
3.3.3.2	Markovnikoff's rule		2
3.3.3.3	carbonium ions in addition reaction		3
3.3.3.4	relative stability of carbonium ions		3
3.3.3.5	1,4-addition to alkadiene	3	

3.4 Alkynes

3.4.1	linear geometry	1
3.4.2	acidity	2
3.4.3	differences in chemical properties between alkenes and alkynes	3

3.5 Arenes and heterocycles

3.5.1	formula of benzene	1
3.5.2	delocalization of electrons	1
3.5.3	stabilization by resonance	1
3.5.4	Hückel (4n + 2) rule	3
3.5.5	aromaticity of heterocycles	3
3.5.6	nomenclature of heterocycles (IUPAC)	3
3.5.7	polycyclic aromatic compounds	3
3.5.8	effect of first substituent on reactivity	2
3.5.9	effect of first substituent on direction of substitution	2
3.5.10	explanation of substituent effects	3

3.6 Halogen compounds

3.6.1	hydrolytic reactions		2
3.6.2	exchange of halogens		3
3.6.3	reactivity (primary vs secondary vs tertiary)		2
3.6.4	ionic mechanism of substitution		2
3.6.5	side products (elimination)		2
3.6.6	reactivity (aliphatic vs aromatic)		2
3.6.7	Wurtz (RX + Na) reaction	3	
3.6.8	halogen derivatives and pollution		3

3.7 Alcohols and phenols

3.7.1	hydrogen bonding - alcohols vs ethers	1
3.7.2	acidity of alcohols vs phenols	2
3.7.3	dehydration to alkenes	1
3.7.4	dehydration to ethers	2
3.7.5	esters with inorganic acids	2

3.7.6	iodoform reaction	2
3.7.7	reactions of primary/secondary/tertiary: Lucas reagent	2
3.7.8	formula of glycerin	1

3.8 Carbonyl compounds

3.8.1	nomenclature	1
3.8.2	keto/enol tautomerism	2
3.8.3	**Preparation of carbonyl compounds**	
3.8.3.1	oxidation of alcohols	1
3.8.3.2	from carbon monoxide	3
3.8.4	**Reaction of carbonyl compounds**	
3.8.4.1	oxidation of aldehydes	1
3.8.4.2	reduction with Zn metal	2
3.8.4.3	addition of HCN	2
3.8.4.4	addition of $NaHSO_3$	2
3.8.4.5	addition of NH_2OH	2
3.8.4.6	aldol condensation	3
3.8.4.7	preparation of acetates	2
3.8.4.8	Cannizzaro ($PhCH_2OH$ disproportionation)	3
3.8.4.9	Grignard reaction	2
3.8.4.10	Fehling (Cu_2O) and Tollens (Ag mirror)	2

3.10 Carboxylic acids

3.10.1	inductive effect and strength	2
3.10.2	equivalence of oxygen atoms in anions	2
3.10.3	**Preparation and reactions of carboxylic acids**	
3.10.3.1	preparation from esters	2
3.10.3.2	preparation from nitriles	2
3.10.3.3	products of reaction with alcohols (esters)	1
3.10.3.4	mechanism of esterification	2
3.10.3.5	isotopes in mechanism elucidation	3
3.10.3.6	nomenclature of acid halides	2
3.10.3.7	preparation of acid chlorides	2
3.10.3.8	preparation of amides from acid chlorides	2
3.10.3.9	preparation of nitriles from acid chlorides	3
3.10.3.10	properties and preparation of anhydrides	2
3.10.3.11	oxalic acid, name and formula	1
3.10.3.12	multifunctional acids (e.g. hydroxyacids, ketoacids)	2
3.10.3.13	polycarboxylic acids	2
3.10.3.14	optical activity (e.g. lactic acid	2
3.10.3.15	R/S nomenclature	3
3.10.3.16	plant and animal fats, differences	2

3.11 Nitrogen compounds

3.11.1	basicity of amines	1
3.11.2	comparing aliphatic vs aromatic	2
3.11.3	names: primary, secondary, tertiary, quaternary amines	2
3.11.4	identification of primary/sec./tert./quaternary amines in laboratory	3

3.11.5	**Preparation of amines**	
3.11.5.1	from halogen compounds	2
3.11.5.2	from nitro compounds (e.g. $PhNH_2$ from $PhNO_2$)	3
3.11.5.3	from amides (Hoffmann)	3
3.11.6	mechanism of Hoffmann rearrangement in acidic/basic medium	3
3.11.7	basicity amines vs amides	2
3.11.8	diazotation products of aliphatic amines	3
3.11.9	diazotation products of aromatic amines	3
3.11.10	dyes: colour vs structure (chromophore groups)	3
3.11.11	nitro compounds : aci/nitro tautomerism	3
3.11.12	Beckmann (oxime - amide) rearrangements	3

3.12 Some large molecules

3.12.1	hydrophilic/hydrophobic groups	2
3.12.2	micelle structure	3
3.12.3	preparation of soaps	1
	products of polymerization of:	
3.12.4	- styrene	2
3.12.5	- ethene	1
3.12.6	- polyamides	3
3.12.7	- phenol + aldehydes	3
3.12.8	- polyuretanes	3
3.12.9	polymers cross linking	3
3.12.10	chain mechanism of polymer formation	2
3.12.11	rubber composition	3

4. BIOCHEMISTRY

4.1 Aminoacids and peptides

4.1.1	ionic structure of aminoacids	1
4.1.2	isoelectric point	2
4.1.3	20 aminoacids (classification in groups)	2
4.1.4	20 aminoacids (names and structures)	3
4.1.5	ninhydrin reaction (including equation)	3
4.1.6	separation by chromatography	3
4.1.7	separation by electrophoresis	3
4.1.8	peptide linkage	1

4.2 Proteins

4.2.1	primary structure of proteins	1
4.2.2	-S-S- bridges	3
4.2.3	sequence analysis	3
4.2.4	secondary structures	3
4.2.5	details of alpha-helix structure	3
4.2.6	tertiary structure	3
4.2.7	denaturation reaction by change of pH, temperature, metals, ethanol	2
4.2.8	quaternary structure	3
4.2.9	separation of proteins (molecule size and solubility)	3
4.2.10	metabolism of proteins (general)	3
4.2.11	proteolysis	3

4.2.12	transamination		3
4.2.13	four pathways of catabolism of amino acids		3
4.2.14	decarboxylation of amino acids		3
4.2.15	urea cycle (only results)		3

4.3 Fatty acids and fats

4.3.1	IUPAC names from C_4 to C_{18}		2
4.3.2	trivial names of most important (ca. 5) fatty acids	2	
4.3.3	general metabolism of fats		2
4.3.4	beta-oxidation of fatty acids (formulas and ATP balance)		3
4.3.5	fatty acids and fats anabolism		3
4.3.6	phosphoglycerides		3
4.3.7	membranes		3
4.3.8	active transport		3

4.4 Enzymes

4.4.1	general properties, active centres	2	
4.4.2	nomenclature, kinetics, coenzymes, function of ATP, etc.		3

4.5 Saccharides

	glucose and fructose:		
4.5.1	- chain formulas		2
4.5.2	- Fischer projections		2
4.5.3	- Haworth formulas		3
4.5.4	osazones		3
4.5.5	maltose as reducing sugar		2
4.5.6	difference between starch and cellulose		2
4.5.7	difference between alpha- and beta-D glucose		2
4.5.8	metabolism from starch to acetyl-CoA		3
4.5.9	pathway to lactic acid or to ethanol; catabolism of glucose		3
4.5.10	ATP balance for the above pathways		3
4.5.11	photosynthesis (products only)		2
4.5.12	light and dark reaction		3
4.5.13	detailed Calvin cycle		3

4.6 Krebs cycle and respiration chain

4.6.1	formation of CO_2 in the cycle (no details)		3
4.6.2	intermediate compounds in the cycle		3
4.6.3	formation of water and ATP (no details)		3
4.6.4	FMN and cytochromes		3
4.6.5	calculation of ATP amount for 1 mole of glucose		3

4.7 Nucleic acids and protein synthesis

4.7.1	pyrimidine, purine		2
4.7.2	nucleosides and nucleotides		3
4.7.3	formulas of all pyrimidine and purine bases		3
4.7.4	difference between ribose and 2-deoxyribose		3
4.7.5	base combination CG and AT		3
4.7.6	base combination CG and AT - (hydrogen bonding structure)		3

4.7.7	difference between DNA and RNA		3
4.7.8	difference between mRNA and tRNA		3
4.7.9	hydrolysis of nucleic acids		3
4.7.10	semiconservative replication of DNA		3
4.7.11	DNA-ligase		3
4.7.12	RNA synthesis (transcription) without details		3
4.7.13	reverse transcriptase		3
4.7.14	use of genetic code		3
4.7.15	start and stop codons		3
4.7.16	translation steps		3

4.8 Other biochemical problems

4.8.1	hormones, regulation		3
4.8.2	hormones, feedback		3
4.8.3	insulin, glucagon, adrenaline		3
4.8.4	mineral metabolism (no details)		3
4.8.5	ions in blood		3
4.8.6	buffers in blood		3
4.8.7	haemoglobin; function and skeleton		3
4.8.8	haemoglobin; diagram of oxygen absorption		3
4.8.9	steps in clotting the blood		3
4.8.10	antigens and antibodies		3
4.8.11	blood groups		3
4.8.12	acetyl choline, structure and functions		3

OTHER PROBLEMS

5. Analytical chemistry

5.1	choice of indicators for acidimetry	1	
5.2	titration curve; pH (strong and weak acid)		2
5.3	EMF (redox titration)		2
5.4	calculation of pH of simple buffer solution		2
5.5	identification of Ag^{+}, Ba^{2+}, Cl^{-}, SO_4^{2-}		1
5.6	identification of Al^{3+}, NO_2^{-}, NO_3^{-}, Bi^{3+}		2
5.7	identification of VO_3^{-}, ClO_3^{-}, Ti^{4+}		3
5.8	use of flame tests for identification of K, Ca a Sr		1
5.9	Beer-Lambert law		2

6. Complexes

6.1	writing down complexation reactions		1
6.2	definition of coordination number	1	
6.3	prediction of coordination number of complex ions and molecules		3
6.4	complex formation constants (definition)		2
6.5	E_g and T_{2g} terms: high and low spin octahedral complexes		3
6.6	calculation of solubility of AgCl in NH_3 (from K_s and constants β)	3	
6.7	cis and trans forms		3

7. Theoretical chemistry

7.1	energy levels of hydrogen atom (formula)	2
7.2	square of the wave function and probability	3
7.3	understanding the simplest Schrödinger equation	3
7.4	n, l, m quantum numbers	2
7.5	shape of p-orbitals	2
7.6	d orbital stereoconfiguration	3
7.7	molecular orbital diagram: H_2 molecule	2
7.8	molecular orbital diagram: N_2 and O_2 molecules	3
7.9	bond orders in O_2, O_2^+, O_2^-	3
7.10	unpaired electrons and paramagnetism	2
7.11	Hückel theory for aromatic compounds	3
7.12	Lewis acids and bases	2
7.13	hard and soft Lewis acids	3

8. Instrumental methods of determining structure

8.1 UV-VIS spectroscopy

8.1.1	identification of aromatic compound	3
8.1.2	identification of chromophore	3

8.2 Mass spectra

	recognition of:	
8.2.1	- molecular ion	3
8.2.2	- fragments with a help of a table	3
8.2.3	typical isotope distribution	3

8.3 Infrared spectra

8.3.1	interpretation using a table of group frequencies	3
8.3.2	recognition of hydrogen bonds	3
8.3.3	Raman spectroscopy	3

8.4 NMR

8.4.1	interpretation of simple spectrum (like ethanol)	3
8.4.2	spin-spin coupling	3
8.4.3	coupling constants	3
8.4.4	identification of o- and p- substituted benzene	3
8.4.5	^{13}C- NMR	3

8.5 X-rays

8.5.1	Bragg law	3
8.5.2	electron density diagram	3
8.5.3	coordination number	3
8.5.4	unit cell	3
	structures:	
8.5.5	- of NaCl	3
8.5.6	- of CsCl	3
8.5.7	- close-packed (2 types)	3
8.5.8	determining of the Avogadro constant from X-ray data	3

8.6 Polarimetry

8.6.1	calculation of specific rotation angle	3