Syllabus of the International Junior Science Olympiad - IJSO

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Aims of the syllabus

The syllabus of the International Junior Science Olympiad (IJSO) lists the skills and areas of knowledge the participants should be familiar with for this competition.

It thus serves as a guideline for developing tasks to the Scientific Committees of the hosting countries but should also help the leaders of the participating countries to effectively train their students for this competition.

In order to keep the syllabus up to date it should be revalidated every three years and if necessary shortened or expanded.

Structure and content of the syllabus

The International Junior Science Olympiad is a general science competition. The IJSO syllabus is therefore not strictly divided into the disciplines biology, chemistry and physics but rather intends to highlight basic general concepts in science.

This conceptual approach is also meant to encourage the development of problems of interdisciplinary content and relevance.

The content of the syllabus is based on

- the former syllabus of the IJSO,
- the syllabi for students up to 15 years of age in the participating countries,
- past IJSO examination papers
- the recommendations of the IJSO International Board

Remarks about problems given at the IJSO

More complex or additional topics may be investigated in the problems provided sufficient information to work on the questions is given in the problems themselves. This may include topics in science that are not listed below as well as the use of sophisticated apparatus in the experiments. The additional topics will not compose more than 10 % of any paper.

All Problems should be given using SI-units. If other units are used the conversion to SI-units should be explained. A list including all the natural constants used in the tests should be provided.

The experimental problems at the IJSO should only employ equipment that most of the students are familiar with and that may be found at schools. Furthermore they should not involve dissection of animals.

A. General science skills

As a general prerequisite the students should be familiar with and be able

- to employ and explain scientific methods, use scientific terminology,
- put forward hypotheses,
- devise and accurately describe methods/experiments to test hypotheses, assess the
- validity of different sources of information and be aware that data might be
- inaccurate or even wrong,
- adequately represent data in tables, diagrams and graphs, interpret
- data.

Scientific methods and measurements	1-1	Scientific method (use, analysis, and explanation): hypothesis, prediction, experiment plan (methods, controls), conclusions. Use of scientific terminology
	1-2	Data in an experiment: representation in tables, diagrams, graphs, biological drawings. Data interpretation. Data validation.
	1-3	Precision and accuracy
	1-4	SI units, derived units, units and dimensional analysis
	1-5	Units (SI) for length, mass, time, temperature, volume, density, pressure, displacement, speed, velocity, acceleration, force, potential difference, current, resistance, electrical power, energy, amount of substance
	1-6	Significant figures (reading measurements, use in calculations (divisions, multiplications, subtractions, and additions only))
	1-7	Identification of error sources**
	1-8	Scientific notation and rounding
	1-9	All non-numerical answers should in agreement with the SI system provided on the IJSO website.

B. Content Knowledge in Natural Sciences and Mathematics

1. Particles, waves and matter

Matter is structured from the smallest particle to the size of the universe. The microscopic structure of matter is responsible for the features we observe macroscopically. The students should be aware of this structure and be familiar with the following concepts:

Properties of matter	2-1	Law of conservation of mass
	2-2	States of matter and its properties
	2-3	Gasses, liquids, solids, plasmas
	2-4	Volume, shape, and particle movement in states of matter

	2-5	Temperature and pressure on states of matter, phase transitions and latent heat
	2-6	Water and its different phases, phase diagrams of water
	2-7	Chemical constituents of matter (elements, compounds, mixtures)
Elements and periodic table	**2-8**	Atomic theory of matter
	2-9	Subatomic particles (electrons, protons, and neutrons), atomic number and mass number
	2-10	Isotopes and atomic mass, atomic mass unit, molecular mass, concept of formula mass, Avogadro's constant, molar mass
	2-11	Atomic structure in terms of electron shells
	2-12	Electron configurations of simple atoms and ions of first 20 elements
	2-13	Concept and modern basis of the Periodic Table
	2-14	Patterns in the Periodic Table: first ionization energy, boiling point, melting point, hardness, electronegativity, electron affinity
	2-15	Metallic nature with respect to non-transition elements
	2-16	Metals, metalloids, and non-metals
	2-17	Oxides and their acid-base nature
	2-18	Chemical formulas of molecular and ionic substances, acids, and corresponding anions
	2-19	Binary molecular and ionic compounds
	2-20	Chemical formulas: empirical formula and molecular formula based on elemental analysis
Gaseous state	2-34	Boyle's law, Charles's law, combined gas law relating volume, temperature, and pressure
	2-35	Avogadro's law, Ideal gas law
	2-36	Partial pressure and moles fraction of a gas in a gas mixture
	2-37	Diffusion and effusion**

2. Energy

Energy is essential in our everyday life as energy conversion is the reason for many dynamical phenomena in our world. Energy is therefore one of the main concepts in science. The students are expected to know about the following topics:

Chemical reactions in terms of energy	2-32	Exothermic and endothermic reactions
	2-33	Enthalpy of reactions (combustion, formation, hydration and phase changes). Calculations using the Hess's law, simple calculations based on enthalpy diagrams
Electricity and chemistry	2-63	Electrochemical cells: The structure of electrochemical cells (electrodes, electrolytes, salt bridges)
	2-64	Definitions of anodes and cathodes based upon their electron exchange, and the direction of current flow between electrodes in electrochemical cells base on standard electrode potentials**
	2-65	Half-cell reactions and full reaction equations leading to the determination of the quantities of electrons transferred in these cells

	2-66	Applications of electrolysis: Electrode reactions and products of the electrolysis of molten NaCl

Energy, work, and power	3-30	Energy conservation, energy conversion/transformation, sources of energy, nature of energy
	3-31	Types of energy (mechanical (potential and kinetic), thermal, electromagnetic, chemical, nuclear**)
	3-32	Transfer of energy (e.g. mechanisms of heat transfer, transfer of energy via waves**)
	3-33	Work of constant force, work-energy theorem, the mass-energy relation
	3-34	Power, relation between transmission of energy and power and efficiency
	3-35	Effects of utilization of energy on life and the environment
	3-36	Fossil fuels**
	3-37	Renewable and non-renewable resources**

3. Interactions

Conversion of energy and our perception of the world around us are only possible due to interactions. The students should know about and be able to work with the following concepts:

Calculations in chemistry	2-21	Mole concept in chemical reactions, converting mass to mole and mole to mass, mass percentages
	2-22	Yield of chemical reactions
	2-23	Molar concentration
	2-24	Dilution of solutions
Chemical reactions	2-25	Balancing chemical equations
	2-26	Qualitative solubility of ionic compounds using solubility data tables provided
	2-27	Precipitation reactions
	2-28	Acid-base reactions
	2-29	Oxidation number rules, oxidation-reduction reactions (combination, decomposition, displacement, and combustion reactions)
	2-30	Half reaction method for balancing oxidation-reduction reactions
	2-31	Net ionic equations

Chemical bonding	2-38	Ionic, covalent, metallic bonds and polar covalent bonds
	2-39	Properties of ionic and covalent compounds, metals, and compounds forming covalent lattices
	2-40	Intermolecular forces, van der Waals forces in polar and nonpolar molecules
	2-41	Hydrogen bonding
	2-42	Dependence of physical properties on intermolecular forces
Reaction rates	2-43	Definition of reaction rate: Instantaneous rate and average rate, rate expressions
	2-44	Factors affecting rates of reactions
	2-45	Determination of rate constant (first order only) from experimental data
Equilibrium	2-46	Equilibrium conditions in reactions
	2-47	Equilibrium constant in both homogeneous and heterogeneous equilibria
	2-48	Calculation of equilibrium concentrations

	2-49	Effect of removing products, addition of reactants and temperature on the direction of reactions
	2-50	Effect of catalysts on the equilibrium
	2-51	Acids and bases and acid base equilibria
	2-52	Strong and weak acids and bases
	2-53	Arrhenius, Bronsted-Lowry, and Lewis concepts**
	2-54	Conjugate acid base pairs
	2-55	Self-ionization of water and pH
	2-56	Calculation of pH in aqueous solutions of strong acids and strong bases
	2-57	pH scale and indicators
	2-58	Degree of ionization, Ka and Kb for weak acid and base, respectively
	2-59	Acid base titration curves and choice of indicators
	2-60	Common ion effect*
	2-61	Buffer solutions: Composition of buffer solutions, qualitative interpretation of the action of buffer solutions
	2-62	Calculation of solubility product and solubility using data provided

Oscillation and waves	3-38	Harmonic oscillations and motion (frequency, period)
	3-39	General wave properties
	3-40	Reflection and refraction of waves
	3-41	Basic principles of diffraction, interference, and superposition of waves*
	3-42	Difference between transverse and longitudinal waves
	3-43	Mathematical relation among the velocity of waves, frequency and wavelength
Light and optics	3-44	Characteristics of light, light travelling, shadows form, linear spreading of light
	3-45	Reflection and refraction of light
	3-46	Spherical lenses*; spherical and plane mirrors
	3-47	Electromagnetic spectrum, visible spectrum, colours and their relation to their wavelength
	3-48	Dispersion of light *
	3-49	Photoelectric effect **
Sound	3-50	Characteristics of sound
	3-51	Sound as a wave
	3-52	Functions of microphone and speaker **
	3-53	Sound as longitudinal pressure wave
	3-54	Perception of a sound **
	3-55	Classical doppler effect for sound
Electricity and magnetism	3-56	Electrical characteristics of materials
	3-57	Static electricity/Coulomb law
	3-58	Dynamic electricity/Ohm law
	3-59	Electric interaction
	3-60	Electric circuit-flow of charge, electric current
	3-61	Electric energy, work and capacity of electric power
	3-62	Electric source, electric potential and electromotive force
	3-63	Electric field

	3-64	Motion of charged particles
	3-65	Series, parallel circuits and Kirchhoff's laws
	3-66	Resistance, conductance and dielectrics**
	3-67	Semiconductor diodes**
	3-68	Magnetic phenomena: magnets and magnetic materials, magnetic field and poles
	3-69	Difference between AC and DC **
	3-70	Electromagnetic induction and Lenz's law**
	3-71	Safe practices in the use of electricity
	3-72	Principles of generators, transformers, and motors **
Heat and mass transfer	3-73	Thermodynamical systems, properties and temperature
	3-74	Thermal conduction, convection, radiation, evaporation and insulation *
	3-75	Specific heat capacity and calorimetry
	3-76	Changes in state of substances and latent heat
	3-77	First law of thermodynamics
	3-78	Pascal's Law
	3-79	Kinetic molecular model of matter **
	3-80	Basics of Bernoulli principles *
Elementary nuclear science	3-81	Isotopes, radioactivity, and half-life **

4. Structure, properties and functions

The different constituents of a system usually have specific properties which allow them to fulfil their function in the intended way. The students should know the structure of the following components and understand in which way they fulfil their functions

Earth, astronomy, space, universe	3-82	Solar system: Sun, moon, planets, and Kepler's laws**
	3-83	Structure of the universe **

Biochemistry	4-1	Chemical composition* of living organisms (organic and inorganic)
	4-2	Structure and functions of molecules (and their monomers): carbohydrates, proteins, nucleic acids, lipids (**)
	4-3	Nutrition and nutrients: macronutrients and micronutrients (*)
Diversity and structure of life	4-4	Characteristics* of living organisms
	4-5	Principles of taxonomy and classification of living organisms; principle of phylogenetic trees and cladistics
	4-6	Organisation levels: cells to tissues to organs to organic system to organism
	4-7	Characteristics* of monera, protists, plants, fungi, and animals
	4-8	Microorganisms and pathogens*
	4-9	Viruses**
	4-10	Asexual and sexual reproduction
Cell biology	4-11	The cell as a system
	4-12	Cell structures and their functions: cell wall, membrane, vacuole, cytoplasm, nucleus, ribosome, chloroplast, mitochondrion
	4-13	Structural characteristics of plant, animal, and bacterial cells

	4-14	Substances exchange at the cellular level (passive (diffusion and osmosis); active transportation)
	4-15	Cellular respiration: aerobic* and anaerobic (**, fermentation and its use in biotechnology)
	4-16	Haploidy and diploidy
	4-17	Gametogenesis
	4-18	Cell cycle (diagram) and cell division (**)
	4-19	Mitosis, meiosis (**, restricted to the types of cells produced and their ploidy)

Preventive biology	4-61	Effect** of some psychotropic substances (tobacco, alcohol, opioid-like drugs) on the human body
	4-62	Effects** of genetic factors, lifestyle, and environmental factors on long term human health
	4-63	Protective function of the immune system and vaccination
	4-64	Microorganisms causing common and infectious diseases
	4-65	HIV and AIDS

5. Systems

Things in life are organized in open or closed systems. It is therefore important to not only look at the components of a system and its interdependencies but also at the system as a whole. The students should be able to employ the concepts of

Plant structure and function	4-28	Primary plant tissues (structure and role in the organism): assimilation, covering, support, circulation tissues
	4-29	Plant nutrition (soil and mineral nutrients)
	4-30	Plant hydrophysiology* (absorption by roots, transpiration)
	4-31	Photosynthesis: outline of C3* and a purpose of C4 and CAM pathways (**)
	4-32	Factors* that affect the rate of respiration and photosynthesis
	4-33	Phytohormones* - location and functions of auxins, gibberellins, ethylene and abscisic acid
	4-34	Responses to signals* (tropism and other plant movements)
	4-35	Reproductive behaviour in plants* (strategies of pollination and seed dispersion).
	4-36	Structures and processes* of sexual reproduction of angiosperm
	4-37	Vegetative reproduction
Animal structure and function	4-38	Animal tissues and their role* in the organism: epithelium, connective (blood, bones), muscular, and nervous tissues.
	4-39	Support systems* in animals
	4-40	Animal nutrition
	4-41	Comparison** of the alimentary systems in carnivores, herbivores, and omnivores
	4-42	Sense organs and their functions using various communication cues (including pheromones and other signals) (*)
	4-43	Animal orientation in space (*)
	4-44	Patterns of reproduction including types of fertilisation (*)
	4-45	Hormone role* in sexual development and maturation of gametes
	4-46	Metamorphosis*
	4-47	Human anatomy and physiology (form and function relationship)

Principles of human biology	4-48	Integumentary system (skin and tissue)
	4-49	Skeletal system and properties of muscles
	4-50	Blood and the circulatory System
	4-51	Digestive system
	4-52	Respiratory system
	4-53	Excretory system
	4-54	Endocrine system
	4-55	Nervous system
	4-56	Sensory organs
	4-57	Reproductive system
	4-58	Human fertilization
	4-59	Human reproductive organs and sex cells
	4-60	Changes that take place in adolescent bodies during puberty

6. Development and Evolution

Living organisms are not static and undergo constant change and adaption. The students are expected to show proficiency in the following areas:

Genetics	4-20	Chromosomal basis of inheritance and variation of traits*
	4-21	Gene as a part of chromosome
	4-22	Replication of DNA**
	4-23	Mendel law of genetics (alleles; dominant and recessive; homo and heterozygotes; first and second law, family pedigree, sex-linked inheritance in humans)
	4-24	Monohybrid crossing
	4-25	Mutation* (mechanisms and genetic defects)
Principles of evolution	4-26	Theory of evolution*
	4-27	Natural selection*

Ecology	4-66	The role of organisms in the circulation of matter and energy in nature
	4-67	Biogeochemical cycles: the cycle of water, carbon, oxygen, and nitrogen in nature
	4-68	Producers, consumers, and decomposers
	4-69	Food chains and webs
	4-70	Factors* affecting ecosystems (abiotic and biotic)
	4-71	Major biotic and abiotic components of terrestrial and aquatic ecosystems
	4-72	Strategies of environmental adaptation: (characteristics of adaptation, structural, physiological, and behavioural adaptation)
	4-73	Interactions between organisms (competition, predation, symbiosis)
	4-74	Factors* affecting growth of populations, typical growth-curves for populations
	4-75	Reproductive behaviour in animals (courtship, mating, and parental care)
	4-76	Ecological balance and natural selection as one process for maintaining this balance
	4-77	Ecological succession*
	4-78	Pollution*: acid rain, global warming, and carbon footprint

	4-79	Human activity in ecosystems and its effects on biodiversity and sustainable development

7. Mathematics skills

The emphasis of the tests should be on natural sciences. Nevertheless mathematics is an indispensable tool to the natural sciences. The students should therefore know about and be able to make use of

Mathematical skills	1-10	Equations involving: fractions, logarithms, powers and roots, polynomials [e.g. solving quadratic equations], trigonometric functions. Plot of the named functions only
	1-11	Transformations of equations to obtain linear relations
	1-12	Basic geometry and fundamentals of stereometry (*): triangles and circles, areas of basic planar forms, volumes, and surface area of basic solid figures
	1-13	Basic vector algebra (*) (decomposition and addition of vectors)
	1-14	Mean values, qualitative concept of uncertainty in measurements**

C. Laboratory Skills

The content knowledge and general science skills part of the Syllabus provide the basis for all the experimental problems. In addition the students should be familiar with laboratory work. They should in particular be able to work in the laboratory following safety regulations

Practical skills	1-15	Work in the laboratory following safety regulations
	1-16	Measurement of mass, length, volume, time, temperature, voltage, and current.
	1-17	Use of dichotomous keys
	1-18	Dissection of plant specimens: roots, stems, leaves, fruits, and flowers.
	1-19	Light microscopy, including the preparation of slides
	1-20	Preparation of standard solutions
	1-21	Titrations
	1-22	Spectrophotometry*: determination of concentrations of solutions by using Beer-Lamberts law with formula provided
	1-23	Basic separation techniques*: filtration, simple distillation, crystallization, thin-layer chromatography, adsorption, centrifugation
	1-24	Measurement of pH in liquids
	1-25	Measurement of focal length of thin lens

Explanation:
** - knowledge of the basis of the phenomemon is needed. For quantitative calculations, formula (diagram, description) must be provided.*
*** - only basic knowledge of the phenomenon is needed. Only qualitative evaluation / application of the phenomenon in simple situations.*