

Syllabus for CCVX Preliminary Examination in Chemistry

This document sets out the general learning outcomes of the programme for the Chemistry Preliminary Examination of the Centrale Commissies Voortentamen (Central Committees for Preliminary Examinations), starting with the November 2017 Preliminary Examination.



This specification is based on the learning outcomes of the programme for the Central Examination and School Examination as held for Chemistry in VWO secondary schools from May 2016. The Preliminary Examination tests knowledge of the syllabus for both the Central Examination and the School Examination.

As long as this list is on the site of the CCVX, this list is automatically up to date. If the syllabus for the Preliminary Examination differs from that of the current programme for the Central Examination or School Examination, the CCVX programme always applies.

Date: 20 September 2020

1. The CCVX Preliminary Examination in Chemistry

The Preliminary Examination is a written examination. It lasts three hours.

The syllabus comprises the following domains:

- Basic Knowledge of Chemistry
- Domain A - Skills
- Domain B - Substances and Materials in Chemistry
- Domain C - Chemical Processes and Laws of Conservation
- Domain D - Development of Chemical Knowledge
- Domain E - Innovation and Chemical Research
- Domain F - Industrial Chemical Processes
- Domain G - Society, Chemistry and Technology

The Physics Preliminary Examination relates to the Basic Knowledge of Chemistry and the Domains B-G in conjunction with the skills in Domain A, except for those aspects that do not by their nature lend themselves to written examination, including skills that expressly require a computer workstation.

For examples of examination questions see the specimen examinations on the CCVX website (www.ccvx.nl) and past written examinations. The type of questions may differ somewhat from those based on the Dutch "College voor Toetsing en Examens" (CvTE) current interpretation of the learning outcomes, as the CCVX preliminary examinations place more emphasis on calculation and less emphasis on language proficiency and reading skills.

The following specification of the syllabus for the CCVX Chemistry Preliminary Examination lists:

- the domains and subdomains being tested
- a single general learning outcome for each subdomain
- the general learning outcomes, supplemented by specimen contexts and specific concepts.

The specimen contexts are intended as minimum requirements; they are certainly not designed to exclude other possible specimen contexts.

2. Syllabus for the Preliminary Examination

Basic Knowledge of Chemistry

The following basic chemical concepts are assumed to be known for the Preliminary Examination.

Pure Substances and Mixtures

The candidate is able to:

sb1 describe what is meant by:

- a pure substance
- a mixture

sb2 describe what is meant by phase transitions:

- condensation and evaporation
- sublimation and deposition
- solidification (freezing) and melting

describe how a mixture can be distinguished from a pure substance:

- melting point/boiling point
- melting range/boiling range

sb4 list various types of mixtures and describe their characteristics:

- solution
- suspension
- emulsion
- alloy

sb5 list various separation/purification techniques, describe for what type of mixture the respective separation technique can be used, and on what principles these techniques are based:

- extraction
- adsorption
- distillation, with the concepts of distillate and residue
- filtration, with the concepts of filtrate and residue
- centrifuging
- precipitation
- concentration by evaporation
- paper chromatography.

Elements and Compounds

The candidate is able to:

sb6 describe what is meant by:

- an element as an atomic species
- an element as a non-decomposable substance
- an element as a decomposable substance

sb7 give the symbols for the following elements given the name, and vice versa, and describe whether the respective element is a metal or a non-metal:

- hydrogen, helium, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminium, silicon, phosphorus, sulfur, chlorine, argon, potassium, calcium, iron, nickel, copper, zinc, bromine, silver, tin, iodine, barium, platinum, gold, mercury, lead, uranium

sb8 give the formulas for the following substances given the name, and vice versa:

- ammonia, bromine, chlorine, fluorine, glucose, iodine, carbon dioxide, carbon monoxide, 'carbonic acid', ozone, nitric acid, nitrogen, water, hydrogen, hydrogen chloride, hydrogen peroxide, oxygen, sulfur dioxide, sulfuric acid

sb9 give and interpret the names and formulas of salts composed of the following ions:

- Ag^+ , Al^{3+} , Ba^{2+} , Ca^{2+} , Cu^{2+} , Fe^{2+} , Fe^{3+} , Hg^{2+} , K^+ , Na^+ , NH_4^+ , Mg^{2+} , Pb^{2+} , Sn^{2+} , Zn^{2+}

- Br^- , CH_3COO^- , Cl^- , F^- , HCO_3^- , I^- , O^{2-} , OH^- , NO_2^- , NO_3^- , PO_4^{3-} , S^{2-} , SO_4^{2-} , SO_3^{2-} .

sb10 interpret the following state symbols:

- (s)
- (l)
- (g)
- (aq).

Atomic structure

The candidate is able to:

sb11 describe the structure of atoms and ions using the concepts of atomic nucleus, proton, neutron, nuclear charge, atomic number, mass number, isotope, electron, electron cloud, ion charge.

Reactions

The candidate is able to:

sb12 describe what is meant by a chemical reaction:

- reactants
- reaction products
- law of conservation of elements
- law of mass conservation

sb13 describe what is meant by a decomposition reaction:

- thermolysis
- electrolysis
- photolysis

sb14 describe what is meant by a combustion reaction:

- complete and incomplete combustion
- ignition temperature

sb15 describe that chemical reactions are associated with a heat effect:

- exothermic
- endothermic

sb16 describe how various substances are detected:

- reagent
- oxygen, hydrogen, water, carbon dioxide, sulfur dioxide.

Acids and Bases

The candidate is able to:

sb17 recognize the following substances/solutions as acids/acid solutions:

- hydrogen chloride/hydrochloric acid
- sulfuric acid/sulfuric acid solution
- nitric acid/nitric acid solution
- 'carbonic acid'/'carbonic acid solution'
- ethanoic acid, acetic acid/vinegar

sb18 recognize the following particles as bases:

- hydroxide ions
- oxide ions
- carbonate ions
- ammonia molecules.

Domain A - Skills

Subdomain A1 - Using Information Skills

The candidate is able to search for, judge, select and process information systematically.

Subdomain A2 - Communication

The candidate is able to communicate effectively on subjects in the respective area in writing, verbally and digitally in the public domain.

Subdomain A3 - Reflecting on Learning

The candidate is able to reflect on his interests, motivation and learning process in acquiring subject knowledge and technical skills.

Subdomain A4 - Studies and Professions

The candidate is able to describe how scientific knowledge is used in studies and professions and based on that, among other things, to put his interest in studies and professions into words.

Subdomain A5 - Research

The candidate is able in particular contexts to analyse problems using relevant concepts and theory, translate them into specific research, conduct that research and draw conclusions from the results, using consistent arguments and relevant arithmetical and mathematical skills.

Specification:

The candidate is able, using consistent arguments and relevant arithmetical and mathematical skills, to:

1. recognize and specify a scientific problem
2. express a scientific problem as one or more research questions
3. identify relationships between a research question and scientific knowledge
4. formulate a hypothesis and expectations for a research question
5. draw up a work plan for a scientific study to answer one or more research questions by means of verification or falsification
6. carry out relevant observations and collect measuring data to answer a research question
7. process measuring data and present them in a way that helps to answer a research question
8. from data collected in a study draw conclusions relating to that study's research question(s)
9. evaluate how a study was conducted and its conclusions, using the concepts of validity, precision, reproducibility and reliability
10. present a scientific study.

Subdomain A6 - Design

The candidate is able in particular contexts to prepare, implement, test and evaluate a technical design based on a set problem, using relevant concepts, theory and skills and valid, consistent arguments.

Specification:

The candidate is able, using relevant concepts, theory and skills and valid, consistent arguments, to:

1. analyse and describe a technical design problem
2. draw up a schedule of requirements and preferences
3. identify relationships between scientific knowledge and the functions and properties of a design
4. produce several versions of the functions and properties of a design
5. put forward a reasoned design proposal for a design, taking the schedule of requirements, priorities and criteria into consideration
6. build a prototype of a design
7. test and evaluate a design process and product, taking the schedule of requirements into consideration

8. put forward proposals to improve a design
9. present a design process and product in appropriate ways.

Subdomain A7 - Modelling

The candidate is able in particular contexts to analyse a relevant problem, reduce it to a workable problem, translate it into a model, generate and interpret model results, and verify and assess the model, using consistent arguments and relevant arithmetical and mathematical skills.

Specification:

The candidate is able, using consistent arguments and relevant arithmetical and mathematical skills, to:

1. identify and select relevant parameters and relationships in a problem situation
2. reduce a scientific problem to a researchable question by making assumptions and simplifications
3. select a model for a scientific problem that is suitable to study it
4. make reasoned estimates of values and margins of error for model parameters based on data
5. formulate verifiable expectations for the behaviour of a model
6. evaluate a model based on results, expectations and measuring data
7. present a model study in appropriate ways.

Subdomain A8 - Scientific Instruments

The candidate is able in particular contexts to use scientifically relevant instruments, paying attention where necessary to risks and safety, namely instruments for data collection and processing, scientific language, scientific conventions, symbols, formulas and arithmetical calculations.

Specification:

The candidate is able to:

1. obtain and select information from written, oral and audiovisual sources, using IT among other things, to:
 - extract data from graphs, tables, drawings, simulations, charts and diagrams
 - look up parameters, units, symbols, formulas and data in appropriate tables
2. analyse information, data and measurements, reproduce and organize them in graphs, drawings, charts, diagrams and tables, using IT among other things
3. explain what is meant by the significance of measured values and give the results of calculations to the correct number of significant digits:
 - when adding and subtracting, giving the result to as many decimal places as the given measured value with the smallest number of decimal places
 - when dividing and multiplying, giving the result to as many significant digits as the given measured value with the smallest number of significant digits
 - integers obtained by counting discrete objects are not covered by the rules for significant digits (this also applies to mathematical constants and monetary amounts)
 - when using logarithms, giving the answer to as many decimal places as the measured value has significant digits.
4. indicate what techniques and devices are used to measure the most important scientific parameters
5. handle materials and instruments without causing harm to humans, animals or the environment
6. use various scientifically relevant arithmetical/mathematical skills to solve scientific problems:
 - use basic arithmetical skills
 - use a graphing calculator

- calculate ratios, percentages, powers and roots
- calculate weighted averages
- do calculations with known parameters and relationships, using the correct formulas and units
- use mathematical techniques:
 - convert simple mathematical relationships
 - solve linear and second-degree equations
 - calculate proportions (direct and inverse)
 - do calculations with logarithm with base 10
 - solve two linear equations with two unknowns
- convert derived units to SI units using conversion tables
- estimate and judge results.

Subdomain A9 - Evaluation and Judgment

The candidate is able in particular contexts to give a reasoned judgment of a situation in nature or a technical application, distinguishing between scientific arguments, normative social considerations and personal views.

Specification:

The candidate is able to:

1. give a reasoned judgment of a situation in which scientific knowledge plays an important role, or make a reasoned choice between alternatives in questions of a scientific nature
2. distinguish between scientific arguments, normative social considerations and personal views
3. cite sources for facts
4. assess the reliability of information and determine its value as regards answering the respective question.

Subdomain A10 - Using Chemical Concepts

The candidate is able to recognize chemical concepts and the physical and biological concepts used in chemistry and relate them to one another.

Specification:

1. The candidate is able to recognize and use the following chemical concepts:
 - aggregation state/phase
 - the state symbols (s), (l), (g) and (aq)
 - alcohols
 - ammonia
 - atomic mass unit (u)
 - greenhouse effect
 - carbon acids
 - coefficient
 - distillate
 - extracting agent
 - phase transition
 - filtrate
 - index
 - indicator
 - mobile phase/eluent
 - molarity/molar (M)
 - caustic soda
 - ignition temperature
 - decomposition reaction: electrolysis, photolysis and thermolysis
 - incomplete combustion
 - solvent

- reagent
 - residue
 - titration
 - trivial name
 - calibration line
 - hydrochloric acid.
2. The candidate is able to recognize and use the following biological concepts:
- respiration
 - blood
 - cell
 - cell membrane
 - chromosomes
 - ecosystem
 - heredity
 - organism
 - digestion
 - transport.
3. The candidate is able to recognize and use the following physics concepts:
- pressure
 - energy
 - force
 - light
 - mass
 - radioactivity
 - potential/voltage
 - radiation
 - current
 - temperature
 - heat.

Subdomain A11 - Reasoning in terms of Context and Concepts

The candidate is able in social (daily life), professional and scientific contexts to recognize and use chemical concepts and on that basis make predictions and estimates and do calculations, giving arguments.

Subdomain A12 - Reasoning in terms of Structure and Properties

The candidate is able to relate macroscopic properties to meso, micro and submicro-level structures, recognizing aspects of scale, and vice versa make predictions on those macroscopic properties based on structures.

The candidate is able to recognize and use the following concepts:

- microstructure/micro level: atoms, molecules, ions
- mesostructure/meso level: structural level created by various groups/grouped particles at micro level
- macrostructure/macro level: level of substances and materials (substance/material properties).

Subdomain A13 - Reasoning about Systems, Change and Energy

The candidate is able to describe chemical processes in terms of systems, using knowledge of substances, particles, reactivity and energy.

Subdomain A14 - Reasoning in terms of Sustainability

The candidate is able in social, professional and scientific contexts to list and describe sustainability aspects, analyse related problems in those terms and formulate proposals for possible solutions.

The candidate is able to:

- describe the role of the life cycles of substances, materials and products in terms of sustainability
- formulate proposals for choosing between alternatives as regards the use of substances and materials in industrial processes, using knowledge of the life cycles of substances, materials and products
- define the social importance of chemistry in the context of sustainability
- relate world problems (global food supply, sustainable energy supply, drinking water, availability of raw materials, global warming and global pollution) to chemical concepts.

Subdomain A15 - Reasoning about the Development of Chemical Knowledge

The candidate is able to analyse how scientific, technological and chemical knowledge is developed and applied.

The candidate is able to:

- describe how scientific knowledge is developed, what questions scientific researchers can pose and how they can arrive at reliable answers (Knowledge Development)
- describe how scientific and technical knowledge is used and describe the interaction between science, technology and society (Application of Knowledge)
- draw conclusions on scientific problems and relate them to the reliability of scientific knowledge (The Influence of Science and Technology).

Domain B - Substances and Materials in Chemistry

Subdomain B1 - Particle Models

The candidate is able to describe and use particle models.

1. The candidate is able to describe the structure of atoms, free radicals and ions, using an atomic model of the nucleus and electrons and the following concepts:
 - structure of the nucleus:
 - protons, neutrons
 - mass number, atomic number
 - isotopes
 - structure of an electron cloud:
 - composed of various shells (K, L, M, ...)
 - maximum number of electrons in the K, L and M shellscharge and mass of electrons, protons and neutrons.
2. The candidate is able to describe the structure of the periodic table and to:
 - describe the relationship between atomic number and position in the periodic table
 - describe the trend in the properties of elements in a group
 - broadly describe the distribution of metals and non-metals
 - describe the position of halogens and noble gases.
3. The candidate is able to use the structure of the periodic table to describe the structure of the electron cloud and to:
 - describe how the properties of groups relate to the structure of the electron cloud
 - describe how the valence of the atomic species relates to the structure of the electron cloud:
 - electrovalence
 - covalence
 - octet rule
 - valence electrons.
4. The candidate is able to use the symbols for the following non-metals given the name, and vice versa:

- argon, boron, bromine, carbon, chlorine, fluorine, helium, hydrogen, iodine, neon, nitrogen, oxygen, phosphorus, silicon, sulfur.
- The candidate is able to use the symbols for the following metals given the name, and vice versa:
 - aluminium, barium, cadmium, calcium, chromium, cobalt, copper, gold, iron, lead, lithium, manganese, magnesium, mercury, nickel, platinum, potassium, silver, sodium, tin, uranium, zinc.
 - The candidate is able to use the molecular formulas for the following substances given the name, and vice versa:
 - acetic acid, ammonia, carbon dioxide, carbon monoxide, glucose, hydrogen chloride, hydrogen peroxide, nitric acid, nitrogen dioxide, nitrogen monoxide, phosphoric acid, sulfur dioxide, sulfur trioxide, sulfuric acid, water
 - the formulas for non-decomposable substances:
 - non-metals
 - metals
 - the first ten alkanes.
 - The candidate is able to give and use the systematic IUPAC names and chemical formulas of salts composed of the following ions:
 Ag^+ , Al^{3+} , Au^+ , Au^{3+} , Ba^{2+} , Ca^{2+} , Cu^{2+} , Fe^{2+} , Fe^{3+} , Hg^+ , Hg^{2+} , K^+ , Li^+ , Mg^{2+} , Na^+ , NH_4^+ , Pb^{2+} , Pb^{4+} , Sn^{2+} , Sn^{4+} , U^{3+} , U^{6+} , Zn^{2+} , Br^- , CH_3COO^- , Cl^- , CO_3^{2-} , F^- , HCO_3^- , I^- , MnO_4^- , NO_3^- , NO_2^- , O^{2-} , OH^- , PO_4^{3-} , S^{2-} , SO_3^{2-} , SO_4^{2-} , $\text{S}_2\text{O}_3^{2-}$.
 - The candidate is able to recognize the following acids:
 HCl , H_2SO_4 , HNO_3 , $\text{H}_2\text{O} + \text{CO}_2$ / ' H_2CO_3 ', H_3PO_4 , CH_3COOH .
 - The candidate is able to recognize the following bases:
 NH_3 , OH^- , CO_3^{2-} , O^{2-} , HCO_3^-
 - The candidate is able to give the chemical formula of a salt based on given ions and give the systematic IUPAC name, and vice versa.
 - The candidate is able to recognize crystallization water in the given formula for a hydrate (notation $\cdot n \text{H}_2\text{O}$).
 - The candidate is able to give the Lewis structure of a given molecular formula, formula for composite ions or structural formula:
 resonance (mesomeric) structures.
 - The candidate is able to describe the position of formal and partial charges in a structural formula/Lewis structural formula.
 - The candidate is able to describe that the molecular formulas for various organic compounds can be the same:
 structural isomerism.
 - The candidate is able to recognize functional/characteristic groups in molecules of organic compounds:
 - $\text{C}=\text{C}$
 - $\text{C}\equiv\text{C}$; (triple bond)
 - OH group (hydroxyl)
 - $\text{C}=\text{O}$ group (aldehyde and ketone)
 - COOH group (carboxyl)
 - NH_2 group (amino)
 - COC group (ether)
 - COOC group (ester)
 - CONHC group (peptide/amide)
 - C-X (X= F, Cl, Br, I).
 - The candidate is able, using the structural formula, to give the systematic IUPAC name for carbon compounds with a branched or unbranched carbon chain and a maximum of ten carbon atoms with no more than one functional/characteristic group, and vice versa:
 - alkanes
 - alkenes
 - alkynes
 - alkanols

- alkanals
- alkanones
- alkanic acids
- alkanic amines
- halogen alkanes
- cycloalkanes
- benzene and benzene derivatives
- alkoxy alkanes
- alkoxy alkanoates.

Subdomain B2 - Properties and Models

Given a described study of substances and materials the candidate is able to explain macroscopic properties using particle models.

1. The candidate is able to describe what is meant by substances and materials in chemistry and reason with them, using the following concept:
 - substance properties (at macro level).
2. The candidate is able to identify a relationship between:
 - a pure substance and melting point/boiling point
 - a mixture and melting range/boiling range.
3. The candidate is able to describe the difference between pure substances and mixtures at micro level.
4. The candidate is able to describe the difference between decomposable and non-decomposable substances at micro level.
5. The candidate is able to describe the difference between a molecular substance and a salt at micro level.
6. The candidate is able to use the following concepts in arguments about mixtures:
 - solution: unsaturated, saturated
 - suspension
 - emulsion, emulsifier
 - alloy
 - homogeneous and heterogeneous mixtures.
7. The candidate is able to relate the above items (B2.1-B2.6) to a described study.

Subdomain B3 - Bonds and Properties

The candidate is able to explain the properties of substances and materials, using knowledge of bonds in and between particles.

1. The candidate is able to describe lattice structures, also using the bonds between the constituent particles:
 - metallic lattice
 - metallic bond
 - ionic lattice
 - ion bond
 - molecular lattice
 - Van der Waals bond/molecular bond
 - dipole-dipole bond
 - hydrogen bridges
 - atomic lattice
 - atomic bond/covalent bond.
2. The candidate is able to explain in a given example that intermediate forms of the lattices referred to in B3.1 are also possible.
3. The candidate is able to give a description of:
 - atomic bond/covalent bond
 - common electron pairs
 - polar atomic bond
 - bonds of N, O or F with other atoms where the partial negative charge is on N, O or F respectively

- ion bond.
4. The candidate is able to relate the strength of the bond between the constituent particles of a substance to phase transitions:
 - ion bond
 - Van der Waals bond/molecular bond
 - hydrogen bridge
 - dipole-dipole bond
 - metallic bond.
 5. The candidate is able to relate differences in solubility/miscibility to the concepts of hydrophobic and hydrophilic.
 6. The candidate is able to relate the terms hydrophobic and hydrophilic to:
 - Van der Waals bond, dipole-dipole bond and hydrogen bridges
 - polar and apolar.
 7. The candidate is able to relate the practical use of a salt to its solubility.

Subdomain B4 - Bonds, Structures and Properties

The candidate is able to explain the properties of substances and materials based on knowledge of structures and the bonds in and between particles, and vice versa predict structures based on the properties of substances or materials.

1. The candidate is able to identify a relationship between the structure of a substance and:
 - electrical conductivity, using:
 - the presence and mobility of charge carriers
 - electrons
 - ions
 - deformability, using:
 - the lattice structure of the substance and lattice errors
 - the presence of plasticizers in polymers
 - the structure of polymer materials:
 - thermoplastics
 - thermosetting plastics
 - UV-light sensitivity, using:
 - crosslinks
 - the presence of multiple atomic bonds
 - corrosion susceptibility, using:
 - standard electrode potential (nobility of metals)
 - the presence of a protective layer.
2. The candidate is able in the case of composites, polymers, alloys and ceramic materials to identify a relationship between the structure/spatial organization of components and the following properties:
 - deformability
 - conductivity
 - water repellence/water binding capacity
 - corrosion susceptibility
 - UV-light sensitivity
 - combustibility
 - hardness
 - brittleness.
3. The candidate is able to describe the spatial structure of composite ions and molecules, or parts thereof, using valence shell electron pair repulsion theory (VSEPR theory):
 - steric numbers 2, 3 and 4
 - steric number = 4: tetrahedral, bond angle approx. 109°
 - steric number = 3: planar, bond angle approx. 120°
 - steric number = 2: linear, bond angle 180° .
4. The candidate is able to conclude from the spatial structure of a molecule, using the charge distribution within it, whether the particle is a dipole.

- The candidate is able to relate the spatial structure of a molecule or parts thereof to the properties of a substance or material:
 - difference between fat and oil
 - secondary structure of proteins.

Domain C - Chemical Processes and Laws of Conservation

Subdomain C1 - Chemical Processes

The candidate is able to describe chemical reactions and processes in terms of reactivity and the formation and breaking of chemical bonds.

- The candidate is able to describe what types of bonds are broken and formed when dissolving the following in water:
 - molecular substances
 - salts:
 - ion-dipole bond, hydration.
- The candidate is able to describe what types of bonds are broken and formed when dissolving and ionizing the following in water:
 - acids:
 - oxonium ion
 - bases.
- The candidate is able to describe what types of bonds are broken/formed for the following processes to take place:
 - evaporation
 - condensation
 - melting
 - solidification.
- The candidate is able to give a reaction equation for the above processes (C1.1 - C1.3).
- The candidate is able to describe what bonds are broken/formed in the following separation processes and, taking that into account, how separation takes place:
 - distillation
 - adsorption.
- The candidate is able to give a reaction equation for the following processes:
 - complete combustion of compounds of carbon, hydrogen and if appropriate oxygen
 - processes in which the reactants and reaction products are known.
- The candidate is able to describe donor/acceptor reactions as reactions in which a particle is transferred, describing which particle is the donor and which the acceptor:
 - acid/base reaction, transfer of protons
 - redox reaction, transfer of electrons.
- The candidate is able in the context of batteries to describe what is meant by an electrochemical cell.
- The candidate is able to describe what is meant by electrolysis:
 - battery charging
 - hydrogen production.
- The candidate is able to describe the difference between weak and strong acids.
- The candidate is able to describe reactions between acids and bases using a reaction equation.
- The candidate is able to describe what buffer systems are and how they work.
- The candidate is able to describe the relative strength of a reducing agent or oxidizing agent using the standard electrode potential.
- The candidate is able in the context of batteries/fuel cells to write equations for half-reactions, given the redox couple.
- The candidate is able to give a reaction equation for a redox reaction using given half-reactions.

16. The candidate is able in the case of organic chemical reactions to describe what bonds are broken and formed, if necessary using resonance (mesomeric) structures:
 - condensation reactions:
 - ester
 - peptide/amide
 - addition reactions to double bond:
 - C=C
 - 1,2 and 1,4 addition.
17. The candidate is able to give the reaction equation for organic chemical reactions in structural formulas and Lewis structures:
 - condensation reactions:
 - ester
 - peptide/amide
 - hydrolysis reactions
 - addition reactions
 - substitution reactions.
18. The candidate is able to describe a reaction with analogue compounds based on a given reaction.

Subdomain C2 - Chemical Calculations

The candidate is able to do calculations on a process, using knowledge of chemical reactions and laws of conservation.

1. The candidate is able to use the following concepts in calculations:

- mass;
 - symbol m
 - unit kg
- volume;
 - symbol V
 - unit m^3
- relative molecular mass;
 - symbol M_r
- chemical quantity;
 - symbol $n(X)$
 - unit mol
- molar mass;
 - symbol $M(X)$
 - unit $g\ mol^{-1}$
- molar volume;
 - symbol V_m
 - unit $m^3\ mol^{-1}$
- density;
 - symbol ρ
 - unit $kg\ m^{-3}$
- concentration;
 - symbol $c(X)$, $[X]$
 - unit $mol\ L^{-1}$
- mass percentage;
 - unit %
- mass-ppm
 - unit ppm, $mg\ kg^{-1}$
- mass-ppb
 - unit ppb, $\mu g\ kg^{-1}$
- volume percentage;
 - unit %
- acidity
 - symbol pH

- $\text{pH} = -\log [\text{H}^+]$; $\text{pH} = -\log[\text{H}_3\text{O}^+]$
 - $\text{pOH} = -\log [\text{OH}^-]$
 - $\text{pH} + \text{pOH} = 14,00$ (bij 298K)
 - $[\text{H}^+] = 10^{-\text{pH}}$; $[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$
 - $[\text{OH}^-] = 10^{-\text{pOH}}$
2. The candidate is able to use the following principles in calculations on and descriptions of chemical processes:
- mass ratio
 - volume ratio of gases in reactions
 - excess/deficiency
 - stoichiometric ratio
 - yield as a fraction or percentage of the theoretical output.

Subdomain C3 - Laws of Conservation and Cycles

The candidate is able to identify relationships between laws of conservation and chemical processes and relate them to cycles.

1. The candidate is able to use the following concepts in arguments:
 - mass conservation/mass balance
 - energy conservation/energy balance
 - charge conservation/charge balance.
2. The candidate is able to relate chemical processes to:
 - substance cycle
 - element cycle
 - recycling
 - cradle to cradle.

Subdomain C4 - Reaction Kinetics

The candidate is able to analyse chemical processes based on knowledge of reaction kinetics, among other things by calculating the concentrations of substances and particles present, and to describe what role is played by catalysis.

1. The candidate is able to explain changes in reaction rate using the particle collision model and the following concepts:
 - surface area of reacting substances
 - concentration
 - temperature.
2. The candidate is able to explain changes in reaction rate using the following concepts:
 - catalyst
 - activation energy.
3. The candidate is able to describe that reactions often take place in steps:
 - reaction mechanism
 - rate-determining step.
4. The candidate is able to calculate the reaction rate in $\text{mol L}^{-1}\text{s}^{-1}$ using data on a reaction.
5. The candidate is able to give a description of the movement of electrons/electron pairs in a given reaction mechanism:
 - nucleophile, electrophile
 - free radicals
 - resonance structures.

Subdomain C5 - Chemical Equilibrium

The candidate is able to describe whether there is equilibrium, to do calculations on equilibrium, and to explain how the position of equilibrium can be influenced.

1. The candidate is able to use the following concepts when describing chemical processes:
 - irreversible reaction
 - reversible reaction
 - equilibrium.

2. The candidate is able to give the condition of equilibrium for a given equilibrium and do calculations on equilibrium:
 - stoichiometric ratio
 - equilibrium constant
 - K_z , K_b , K_w .
3. The candidate is able to explain the influence on the position of equilibrium in terms of:
 - change in the reaction quotient
 - change in the equilibrium constant.
4. The candidate is able to explain the influence of a catalyst on a chemical process:
 - reaction rate
 - time needed to reach equilibrium
 - position of equilibrium.
5. The candidate is able to calculate the pH of a solution with a known concentration of an acid or base, or vice versa calculate the concentration from the pH:
 - strong acid
 - univalent weak acid
 - strong base
 - univalent weak base.

Subdomain C6 - Energy Calculations

The candidate is able to do calculations on energy conversions and energy exchange in chemical processes and draw conclusions and formulate proposals based on them.

1. The candidate is able to give an energy diagram showing the energy effect of a reaction, using:
 - transition state/activated state
 - the influence of a catalyst.
2. The candidate is able to use the following concepts, reasoning about energy conversions in chemical processes:
 - endothermic, exothermic
 - heat of formation
 - activation energy
 - energy diagram.
3. The candidate is able to calculate the heat of a reaction using heat of formation.
4. The candidate is able to calculate and reason using the first law of thermodynamics (the law of conservation of energy):
 - converting chemical energy into other types of energy:
 - heat
 - electrical energy.

Subdomain C7 - Classification of Reactions

The candidate is able to classify reactions and describe them in terms of their characteristics:

- thermolysis, photolysis, electrolysis, hydrolysis, saponification, addition, substitution, precipitation, dissolution, redox, combustion, acid-base, condensation, polymerization, reversible/equilibrium reactions, ester formation, synthesis, free radical mechanism.

Subdomain C8 - Technological Aspects

The candidate is able in technological contexts to recognize and explain aspects of scale, change and reactivity:

- increasing scale
- reactors, reactivity of chemical reactions
- thermal management
- separation techniques, block diagram
- lab-on-a-chip
- nanoproceses
- chemistry of atmospheric radicals.

Subdomain C9 - Quality of Energy

The candidate is able to describe how energy and the quality of energy changes in chemical processes, using knowledge of energy:

- energy transitions
- types of energy
- exothermic, endothermic
- energy diagram.
- heat of formation, fossil fuel, biofuel
- thermodynamic concepts such as Gibbs energy and enthalpy.

Subdomain C10 - Activation Energy

The candidate is able to use and describe the concept of activation energy in experiments and relate it to catalysis:

- activation energy
- catalyst
- enzymes
- energy diagram, element conservation.

Domain D - Development of Chemical Knowledge

Subdomain D1 - Chemical Techniques

The candidate is able to formulate and judge the selection of a particular separation and/or analytical technique, using knowledge of materials and substances.

1. The candidate is able to explain on what difference in substance properties separation techniques are based and argue why they are used in a particular process:
 - filtration
 - centrifuging
 - distillation
 - extraction/washing
 - adsorption
 - precipitation
 - concentration by evaporation.
2. The candidate is able to explain how analytical techniques are used to establish whether a separation technique has been successful, and if so to what extent.
3. The candidate is able to explain on what differences in substance properties chromatography is based.
4. The candidate is able to describe the presence of certain substances using gas chromatography and retention time.
5. The candidate is able to describe that characteristic patterns occur in mass spectra of substances by which those substances can be recognized, and to analyse mass spectra.
6. The candidate is able to calculate the amount of a substance in a solution or mixture from quantitative measurements or explain a given calculation:
 - chromatography: peak area
 - mass spectrometry: peak height.

Subdomain D2 - Safety

The candidate is able to use and describe the concept of activation energy in experiments and relate it to catalysis.

- activation energy
- catalyst
- enzymes
- energy diagram, element conservation.

Subdomain D3 - Chemical Synthesis

The candidate is able to describe how substances are synthesized and relate this to relevant reaction mechanisms, using knowledge of chemical processes.

1. The candidate is able to identify a relationship between the structural formula of a polymer/copolymer and the structural formula(s) of the monomer(s):
 - addition polymers
 - condensation polymers.
2. The candidate is able to describe the various steps in the reaction mechanism of addition polymerization:
 - initiation, propagation, termination.
3. The candidate is able to identify a relationship between the reaction mechanism and:
 - average chain length, degree of polymerization
 - crosslinks.

Subdomain D4 - Molecular Modelling

The candidate is able to write a reaction mechanism using molecular modelling, among other things, and knowledge of catalysis if appropriate:

- reaction steps/mechanism
- catalyst
- polymerization
- monomer
- polycondensation, enantiomers, optical activity.

Domain E - Innovation and Chemical Research

Subdomain E1 - Chemical Research

The candidate is able at least in the context of health, materials or food production to describe, using knowledge of chemical processes, how that knowledge is used in a described study.

1. The candidate is able to describe the relationship between the microstructure and macroscopic properties of substances/materials and to describe how that relationship is used in a described study:
 - mobility of charge carriers and conductivity
 - characteristic groups and reactivity
 - free electron pair
 - free radical
 - multiple atomic bond
 - dipole/polar atomic bond
 - lattices and deformability
 - metallic lattices
 - lattice errors
 - alloys
 - the influence of temperature
 - lattice/structure of polymers
 - plasticizers
 - chain length
 - types of monomers
 - crosslinks
 - crystal structure of ceramic materials
 - ionic lattice
 - atomic lattice
 - the presence of multiple bonds and UV-light sensitivity
 - types of metal atoms and corrosion susceptibility
 - bound metal oxide layer
 - standard electrode potential (nobility of metals)

- molecular structure and solubility
 - characteristic groups
 - hydrophilic/hydrophobic
- molecular structure and water repellence
 - characteristic groups
- molecular structure and biodegradability of polymers
 - characteristic groups.

Subdomain E2 - Selectivity and Specificity

The candidate is able at least in the context of food production, pharmaceuticals or the transport of substances in the body to explain selectivity and specificity in chemical reactions, if appropriate using knowledge of catalysis.

1. The candidate is able to identify a relationship between the structure of an organic molecule and the properties of a substance:
 - stereoisomerism:
 - cis/trans isomerism
 - mirror image isomerism:
 - asymmetrical carbon atom.
2. The candidate is able regarding the mechanism of an enzyme as a biocatalyst to explain the kinetics of the reaction between enzyme and substrate qualitatively using the following concepts:
 - the formation of an enzyme-substrate complex
 - the splitting-off of a product.
3. The candidate is able to describe the specificity and selectivity of an enzyme based on its spatial structure and the functional groups:
 - active position
 - pH optimum
 - temperature optimum.
4. The candidate is able to describe what factors play a role in the transport of substances in the body:
 - pH
 - hydrophobic/hydrophilic
 - membranes.

Subdomain E3 - Sustainability

The candidate is able to evaluate and comment on conclusions regarding sustainability, using knowledge of chemical processes:

- sustainable cycles, aspects of green chemistry
- atom efficiency/economy
- coefficient of pollution
- E-factor
- yield
- fossil fuels, electrochemistry.

Subdomain E4 - New Materials

The candidate is able at least in the context of pharmaceuticals, nutrition or materials to explain how new applications are developed in existing and new markets, using knowledge of the chemical industry:

- nanotechnology
- nanocoatings
- ceramic materials
- molecular structure
- antibiotics
- pharmaceutical research.

Subdomain E5 – Research and Design

The candidate is able at least in the context of sustainability, materials, nutrition or health to formulate a practical research or design assignment, implement it and report on it:

- formulating research question/hypothesis, identifying variables, drawing up a work plan, processing measuring data, drawing conclusions, presentation.

Domain F - Industrial Chemical Processes

Subdomain F1 - Industrial Processes

The candidate is able to describe industrial processes in block diagrams, do calculations on them and formulate and judge proposals for modifications.

1. The candidate is able, given data on an industrial process, to describe that process in a block diagram:
 - substance flows
 - recirculation
 - reactors
 - separation plants
 - heat exchangers.
2. The candidate is able to explain an industrial process using a block diagram:
 - reactions
 - separation techniques
 - energy effect
 - energy management.
3. The candidate is able to use the following concepts when describing an industrial process:
 - catalysis
 - continuous process
 - batch process
 - bulk chemicals/fine chemicals.

Subdomain F2 - Green Chemistry

The candidate is able at least in the context of food production or sustainability to recognize 'principles of green chemistry' and relate them to implemented, possible and desired changes in those processes and do simple calculations, using knowledge of process technology and reaction kinetics.

1. The candidate is able to identify relationships between aspects of green chemistry that have played a role in the design and modification of industrial processes:
 - reaction conditions
 - safety
 - qualitative consideration of energy
 - side reactions
 - choosing between batch process and continuous process
 - by-products
 - incomplete conversion
 - excess/deficiency
 - renewable resources
 - use of water
 - recycling
 - waste
 - environmental requirements.
2. The candidate is able, using given green chemistry formulas, to do calculations on a process:
 - atom economy

- E-factor
 - energy effect
 - yield.
3. The candidate is able to recognize and describe chemical concepts in processes and relate them to proposals for modifications:
- biomass fermentation
 - biodiesel production
 - transesterification
 - oil refinery
 - fractional distillation
 - cracking
 - reforming
 - recycling
 - plastics
 - metals.

Subdomain F3 - Energy Conversion

The candidate is able in the context of sustainability to describe what chemical and/or technological processes are used in energy conversions and to describe these processes and the conditions involved and judge proposals for modifications, using knowledge of energy production.

1. The candidate is able, using a description of the following techniques for producing energy from biomass, to reason about these techniques:
 - fermentation: bioethanol, biogas
 - biodiesel production
 - combustion.
2. The candidate is able to describe how fossil fuels are used in energy production:
 - natural gas, petroleum, coal
 - combustion in a special combustion unit
 - reaction products and pollution
 - steam generation
 - dynamo.
3. The candidate is able to describe the photosynthesis of glucose as a process in which light is converted into chemical energy:
 - capture of carbon dioxide
 - production of oxygen.
4. The candidate is able to compare fuels, judge proposals for modifications and reason about the sustainability aspects involved:
 - difference in the amount of carbon dioxide produced by biofuel and fossil fuel
 - carbon cycle
 - C/H ratio:
 - respective amounts of CO₂ per joule
 - emissions from combustion:
 - CO₂
 - NO_x
 - SO₂
 - environmental factors:
 - fuel delivery
 - fuel storage
 - cooling water.
5. The candidate is able to reason about aspects of sustainability that play a role in the conversion of chemical energy into electrical energy, and vice versa, and to judge proposals for modifications:
 - electrochemical cell/battery/fuel cell
 - describe that a redox reaction occurs in an electrochemical cell in which electrons are transferred via an external connection

- reducing/oxidizing agent
- half-reactions/total reaction
- positive and negative electrode
- electrolyte
- membrane
- charging
- recycling
- energy-mass ratio.

Subdomain F4 - Risks and Safety

The candidate is able to use knowledge of risks and safety and judge those aspects in industrial production processes:

- substance flows, energy flows, risk and probability, change of scale (on a large scale), risk (R) and safety (S) sentences, pictograms, substance flows, energy flows, substance cycles.

Subdomain F5 - Sustainable Production Processes

The candidate is able at least in the context of sustainability to give an opinion on the design of production processes, using chemical knowledge:

- large scale, design, judgment, sustainable cycles, green chemistry, laws of conservation, chemical industry, E-factor, atom economy, coefficient of pollution Q.

Domain G - Society, Chemistry and Technology

Subdomain G1 - The Chemistry of Life

The candidate is able to describe and use knowledge of chemical processes in living organisms.

1. The candidate is able to describe that nutrients are broken down and the decomposition products can provide the basis for the production of self substances.
2. The candidate is able to describe the chemical structure of various substances:
 - proteins:
 - primary, secondary and tertiary structure
 - carbohydrates:
 - monosaccharides, disaccharides and polysaccharides
 - fats:
 - glycerol
 - fatty acids
 - saturated/unsaturated
 - nucleic acids:
 - DNA:
 - deoxyribose
 - bases A, C, T and G
 - phosphates
 - RNA:
 - ribose
 - bases A, C, U and G
 - phosphates.
3. The candidate is able to describe that various nutrients are broken down in the body:
 - proteins:
 - hydrolysis to amino acids
 - urea
 - combustion.
 - carbohydrates:
 - hydrolysis to monosaccharides

- combustion
 - fats:
 - hydrolysis to glycerol and fatty acids
 - combustion.
4. The candidate is able to describe what function various substances perform in the body:
 - proteins:
 - building material
 - enzyme
 - carbohydrates:
 - energy storage
 - glycogen
 - fats:
 - energy storage
 - building material: membranes
 - phospholipids
 - nucleic acids:
 - genetic code
 - protein synthesis:
 - production of mRNA
 - protein synthesis on ribosomes
 - tRNA.
 5. The candidate is able to describe that a small number of substances that form an essential part of the diet cannot be produced by the body:
 - essential amino acids
 - essential fatty acids.

Subdomain G2 - Environmental Impact Assessment

The candidate is able at least in the context of health or sustainability to describe what social conditions play a role in environmental issues, using knowledge of production processes, and what potential consequences these issues have in the area of health and sustainability.

1. The candidate is able to describe what potential consequences a production process has for the environment and health, given data on that process:
 - transport of raw materials, products and waste
 - emissions
 - limits
 - use of cooling water
 - risks in the event of an emergency
 - combined heat and power
 - sustainability.

Subdomain G3 - Energy and Industry

The candidate is able at least in the context of sustainability to describe energy conversions from the various sources, make comparisons and give a reasoned judgment, using knowledge of production processes.

1. The candidate is able to compare various processes in terms of sustainability and justify the choice of a particular process:
 - coal gasification plant
 - natural gas-fired power station
 - coal-fired power station
 - fuel cell.
2. The candidate is able to compare the use of various energy sources in a process and justify the choice of a particular energy source:
 - hydrogen
 - bioethanol
 - biogas
 - biodiesel.

Subdomain G4 - Environmental Requirements

The candidate is able to describe what qualities of water, air, soil and food are guaranteed in what way and judge proposed modifications, using knowledge of large-scale chemical processes:

- green chemistry, natural resources, re-use, cradle to cradle, energy management, water quality, air quality, soil quality, food quality.

Subdomain G5 - Business Processes

The candidate is able at least in the context of sustainability to analyse an example from the Dutch chemical industry and describe what contribution the business process makes to local and global quality of life, using chemical knowledge:

- sustainability, processes, effects on the living environment, quality of life, and so on.