SwissChO 2024 First Round

CHEMISTRY.
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G0-1

English (Official)

General Information

This exam contains	**45 Questions**
Duration	40 minutes
Question types	Multiple Choice (MC)
Grading	Each fully correct reply is worth one point.
Aids and tools	All aids are allowed (textbooks, calculators, periodic table, etc.). However, the exam has to be solved on one's own without the help from others.
Participation conditions (according to IChO)	born on or after 1 July 2004 not yet immatriculated at a university attending a Swiss school (now or previously)
Due date	13 October 2023
Send completed answer sheets to	Wissenschafts-Olympiade Universität Bern Hochschulstrasse 6 3012 Bern

Online participation is recommended. For the print version of the exams and details regarding the participation on paper, see chemistry.olympiad.ch/en/teachers

Good luck!

General Questions

Note that for each questions, one or several answers can be correct. Unless stated otherwise, always assume standard conditions (concentrations of 1 mol L^{-1}, temperature of 298.15 K, pressure of $101\,325$ Pa) and that gases behave ideally.

1.1 How much calcium chloride needs to be weighed out for 0.9 L of a 1.25 mol L^{-1} solution of $CaCl_2$? 1.0pt

A) 124.85 g
B) 84.97 g
C) 79.91 g
D) 154.14 g
E) 29.74 g

1.2 Which atom has the smallest atomic radius? 1.0pt

A) Na
B) Co
C) F
D) Ar
E) Ne

1.3 Which bond is most polar? 1.0pt

A) Si—Si
B) O—H
C) C—F
D) Si—F
E) N—O

1.4 Which of the electron configurations given below corresponds to the most electronegative element? 1.0pt

A) [Ne] $3s^2$
B) [Ne] $3s^2 3p^5$
C) [He] $2s^2 2p^4$
D) [Ar] $4s^1$
E) [Ne] $3s^2 3p^1$

1.5 Which molecule(s) contain(s) <u>at least</u> 5 carbon atoms? 1.0pt

A) 1,1-difluoroethane
B) 3,3-diethylpentane
C) 2-chloro-3-hydroxybutane
D) 2,3-difluoro-4-nitrocyclopentanone

1.6 Which of these elements has the highest boiling point? 1.0pt

A) Helium
B) Tungsten
C) Uranium
D) Silicon
E) Copper

1.7 The pH value of a $0.1\,\text{mol}\,\text{L}^{-1}$ solution of KOH is 1.0pt

A) 4
B) 6.5
C) 13
D) 8
E) 11

1.8 What type of reaction is this: $2\,\text{Au}^{3+} + 3\,\text{Cu} \longrightarrow 2\,\text{Au} + 3\,\text{Cu}^{2+}$? 1.0pt

A) redox
B) precipitation
C) neutralisation
D) condensation

1.9 Which compound(s) is/are isoelectronic to CO? 1.0pt

A) CN^-
B) NO
C) NO^+
D) O_2

1.10 What is the electron configuration of sulphur? 1.0pt

A) $1\text{s}^2 2\text{s}^2 3\text{s}^2 2\text{p}^6 3\text{p}^4$
B) $1\text{s}^2 2\text{s}^2 3\text{s}^2 2\text{p}^6 3\text{p}^6$
C) $1\text{s}^2 2\text{s}^2 2\text{p}^4 3\text{s}^2 3\text{p}^4$
D) $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^4$

1.11 Consider the following exothermic reaction: $\text{N}_2\,(\text{g}) + 3\,\text{H}_2\,(\text{g}) \longrightarrow 2\,\text{NH}_3\,(\text{g})$. Which of the following changes to the reaction will increase the yield of the product? 1.0pt

A) increasing the pressure
B) decreasing the temperature
C) increasing the temperature
D) removing ammonia continuously via distillation

Chemical Buffers

2.1 Which of the following mixtures, when dissolved in water, gives a buffer solution? 1.0pt

A) NaOAc + HOAc
B) NaCl + HCl
C) KCl + KOH
D) HF + HCl

2.2 You prepare $1.0\,\text{L}$ of a buffer solution from $8.203\,\text{g}$ of anhydrous sodium acetate and $3.216\,\text{mL}$ of acetic acid ($\rho = 1.05\,\text{g mL}^{-1}$). What is the resulting pH value? 1.0pt

A) 3
B) 5
C) 6
D) 9

2.3 Now you add $50\,\text{mL}$ of $1\,\text{mol L}^{-1}$ HCl solution to $1\,\text{L}$ of a buffer solution consisting of $8.203\,\text{g}$ of anhydrous sodium acetate and $3.216\,\text{mL}$ of acetic acid ($\rho = 1.05\,\text{g mL}^{-1}$). What is the new pH value? 1.0pt

A) 5.72
B) 5.08
C) 3.29
D) 4.42

2.4 Why are buffer solutions useful in chemistry? 1.0pt

A) They keep the pH value more or less constant
B) They have pretty colours
C) They make any chemical you add to them soluble
D) They allow you to test the pH value of an unknown solution

2.5 Phosphoric acid has three pK_a values: $pK_{a,1} = 2.1$, $pK_{a,2} = 7.2$, $pK_{a,3} = 12.3$. If you want to obtain a phosphate buffer of near-neutral pH, what do you need to add, starting from a solution containing $1\,\text{mol}$ of sodium dihydrogenphosphate? 1.0pt

A) $0.5\,\text{molNaOH}$
B) $1.0\,\text{molNaOH}$
C) $1.5\,\text{molNaOH}$
D) $0.5\,\text{molHCl}$

Acids and Bases

3.1 What is the pH of a solution containing $0.1\,\text{mol L}^{-1}$ acetic acid (pK_a = 4.75)? 1.0pt

A) 4.75
B) 2.88
C) 1.88
D) 6.5

3.2 If you titrate a weak acid with a strong base, what type of compound is present in your titration vessel at the equivalence point? 1.0pt

A) weak acid
B) strong acid
C) weak base
D) strong base

3.3 $100\,\text{mL}$ of $0.1\,\text{mol L}^{-1}$ acetic acid is titrated with a $0.05\,\text{mol L}^{-1}$ solution of NaOH. What volume of NaOH solution is needed to get a final pH value of 4.75? 1.0pt

A) $10\,\text{mL}$
B) $250\,\text{mL}$
C) $500\,\text{mL}$
D) $100\,\text{mL}$
E) $200\,\text{mL}$

3.4 You create a buffer solution using $100\,\text{mL}$ of $0.1\,\text{mol L}^{-1}$ acetic acid and $100\,\text{mL}$ of $0.05\,\text{mol L}^{-1}$ NaOH. What is the final concentration of sodium acetate in this solution? 1.0pt

A) $0.033\,\text{mol L}^{-1}$
B) $0.067\,\text{mol L}^{-1}$
C) $0.05\,\text{mol L}^{-1}$
D) $0.1\,\text{mol L}^{-1}$

3.5 You create a buffer solution using $100\,\text{mL}$ of $0.1\,\text{mol L}^{-1}$ acetic acid and $100\,\text{mL}$ of $0.05\,\text{mol L}^{-1}$ NaOH. You add $10\,\text{mL}$ of this buffer solution to $1.0\,\text{L}$ of $0.1\,\text{mol L}^{-1}$ KOH. What will the resulting approximate pH value be? 1.0pt

A) 7
B) 9
C) 11
D) 13

Chemistry of the Elements

4.1 In order to transport oxygen in their bloodstream, humans use haemoglobin. Which ion is crucial for the correct functioning of this protein? 1.0pt

A) Fe^{+}
B) Fe^{3+}
C) Fe^{2+}
D) Co^{3+}

4.2 Which of the following substances will give an acidic solution when dissolved in water? 1.0pt

A) $NaHSO_4$
B) CH_3COONa
C) NH_4Cl
D) CaO

4.3 Borane (BH_3) is an unstable and somewhat unusual molecule, because 1.0pt

A) its hydrogen atoms do not respect the octet rule
B) its boron atom does not respect the octet rule
C) the hydrogen atoms bond with one another
D) it forms dimers

4.4 What happens during the electrolysis of water with sodium chloride dissolved in it (pH of the solution is zero)? 1.0pt

A) Hydrogen bubbles form at the anode
B) Hydrogen bubbles form at the cathode
C) Chlorine bubbles form at the anode
D) Oxygen bubbles form at the cathode

4.5 RDX, also known as hexogen, is an extremely powerful explosive used by military services around the world. It has a sum formula of $C_3H_6N_6O_6$, and requires some oxygen to fully react. Which reaction equation correctly describes the complete decomposition of RDX? 1.0pt

A) $C_3H_6N_6O_6 + O_2 \longrightarrow 3\,CO_2 + 3\,N_2 + 3\,H_2O$
B) $C_3H_6N_6O_6 + 3\,O_2 \longrightarrow 6\,CO_2 + 3\,N_2 + 6\,H_2O$
C) $C_3H_6N_6O_6 + 5\,O_2 \longrightarrow 9\,CO_2 + 7\,N_2 + 9\,H_2O$
D) $2\,C_3H_6N_6O_6 + 3\,O_2 \longrightarrow 6\,CO_2 + 6\,N_2 + 6\,H_2O$

4.6 Elemental sulphur (1) can be oxidised by burning it in a high-oxygen atmosphere to give sulphur trioxide (2), which can then be combined with water to give sulphuric acid (3). Which assignment of oxidation states to the compounds (1-3) is correct? 1.0pt

A) 1: 0, 2: +VI, 3: +VI
B) 1: 0, 2: +III, 3: +VI
C) 1: -II, 2: 0, 3: +III
D) 1: 0, 2: +IV, 3: +V

4.7 How many grams of pure H_2SO_4 can be created by first burning 160 g of elemental sulfur to create sulfur trioxide and then adding water to produce sulfuric acid? 1.0pt

A) 244.74 g
B) 4894.8 g
C) 489.48 g
D) 24.47 g

4.8 You build a simple battery, using a copper element dipped in a 1.0 mol L^{-1} $CuSO_4$ solution and a zinc element dipped in a 1.0 mol L^{-1} $ZnSO_4$ solution. When you close the circuit, at which voltage will your battery operate? 1.0pt

A) 0.32 V
B) 1.10 V
C) -0.32 V
D) No voltage, the battery doesn't work

Kinetics

Nitric oxide (nitrogen monoxide) reacts with oxygen according to the following reaction equation: $2\,NO\,(g) + O_2\,(g) \longrightarrow 2\,NO_2\,(g)$

The table below shows how the reaction rate changes when the concentration of the reactants is changed:

Experiment no.	Initial c(NO) / mol dm^{-3}	Initial c(O_2) / mol dm^{-3}	Initial reaction rate / mol dm^{-3} s^{-1}
1	0.100	0.100	7.50×10^{-5}
2	0.100	0.200	15.01×10^{-5}
3	0.200	0.100	30.03×10^{-5}
4	0.300	0.100	60.07×10^{-5}

5.1 What is the reaction order with respect to NO and with respect to O_2? 1.0pt

A) 1st order for NO, 1st order for O_2
B) 1st order for NO, 2nd order for O_2
C) 2nd order for NO, 1st order for O_2
D) 2nd order for both

5.2 What is the rate law for the reaction $2\,NO\,(g) + O_2\,(g) \longrightarrow 2\,NO_2\,(g)$? 1.0pt

A) $v = k\,[NO]\,[O_2]$
B) $v = k\,[NO]^3\,[O_2]^2$
C) $v = k\,[NO]^2\,[O_2]^2$
D) $v = k\,[NO]^2\,[O_2]$

5.3 Determine the correct value for the rate constant k for the reaction $2\,NO\,(g) + O_2\,(g) \longrightarrow 2\,NO_2\,(g)$ 1.0pt

A) 7.5×10^{-3} dm^6 mol^{-2} s^{-1}
B) 7.5 dm^6 mol^{-2} s^{-1}
C) 7.5×10^{3} dm^6 mol^{-2} s^{-1}
D) 7.5×10^{6} dm^6 mol^{-2} s^{-1}

Solubility

6.1 The solubility product of silver chloride is $K_S = 2 \times 10^{-10}\,\text{mol}^2\,\text{L}^{-2}$. What is the maximum amount of silver chloride that can be dissolved in $1\,\text{L}$ of water? 1.0pt

A) $1.53 \times 10^{-3}\,\text{g}$
B) $1.31 \times 10^{-7}\,\text{g}$
C) $2.03 \times 10^{-3}\,\text{g}$
D) $1.31 \times 10^{-4}\,\text{g}$

6.2 Seawater contains approximately 3.5 mass-% of sodium chloride. How many mol of NaCl are contained in $5\,\text{L}$ of seawater? 1.0pt

A) $3\,\text{mol}$
B) $4.4\,\text{mol}$
C) $0.23\,\text{mol}$
D) $2.3\,\text{mol}$

6.3 What variables does the solubility of a compound (in $\text{g}\,\text{L}^{-1}$) depend on? 1.0pt

A) colour of the vessel
B) temperature
C) pressure
D) volume of solvent

6.4 Which of the following substances will dissolve readily in room-temperature water? 1.0pt

A) KCl
B) CH_3COONa
C) HCl
D) C_2H_5OH

Thermodynamics

Table of standard formation enthalpies at $25\,°C$ and $101\,325\,Pa$

Compound	ΔH_f^0/kJ mol^{-1}
$CO_2\,(g)$	-393
$H_2O\,(g)$	-242
$H_2O\,(l)$	-286
$C_6H_{12}O_6\,(s)$	-1274

7.1 What is the standard reaction enthalpy for the combustion of glucose, calculated from standard formation enthalpies? 1.0pt

$C_6H_{12}O_6\,(s) + 6\,O_2\,(g) \longrightarrow 6\,H_2O\,(l) + 6\,CO_2\,(g)$

A) -2536 kJ mol^{-1}
B) -595 kJ mol^{-1}
C) 595 kJ mol^{-1}
D) -2800 kJ mol^{-1}

7.2 What is the thermicity of the following reaction: 1.0pt

$C_6H_{12}O_6\,(s) + 6\,O_2\,(g) \longrightarrow 6\,H_2O\,(l) + 6\,CO_2\,(g)$

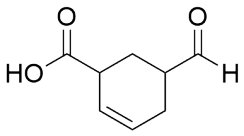
A) endothermic
B) exothermic
C) neither exo- nor endothermic
D) can't say

7.3 We burn an excess of glucose with 2.00 L of pure oxygen under standard conditions. 70% of the reaction enthalpy is transferred into 1000 g of water (heat capacity of water is $4.184\,J\,g^{-1}\,K^{-1}$). Assuming that the initial temperature of the water is $20\,°C$, what is the final temperature of the water? 1.0pt

A) $13.49\,°C$
B) $26.51\,°C$
C) $33.02\,°C$
D) $265.12\,°C$

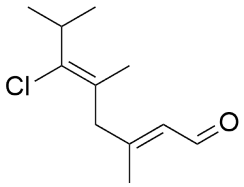
Organic Chemistry

8.1 Which is the functional group with the highest priority in the following molecule? 1.0pt



A) alcohol
B) ketone
C) aldehyde
D) carboxylic acid

8.2 What is the correct stereochemistry of the following molecule? 1.0pt

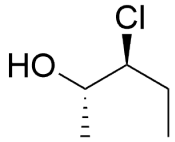


A) (3*Z*,6*E*)
B) (3*E*,6*E*)
C) (2*E*,5*E*)
D) (1*E*,4*E*)
E) (2*E*,5*Z*)

8.3 Which of the following statements about delocalisation and resonance structures is/are correct? 1.0pt

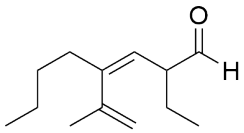
A) Compounds with a benzene ring always have at least two resonance structures
B) Resonance structures with neighbouring charge of the same sign are favoured
C) Resonance structures show compounds that can be isolated
D) Delocalisation talks about how electrons are distributed in a structure

8.4 What is the correct stereochemistry of the following molecule? 1.0pt



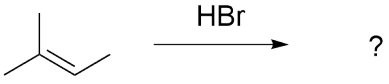
A) (2*S*,3*S*)
B) (2*S*,3*R*)
C) (2*R*,3*S*)
D) (2*R*,3*R*)

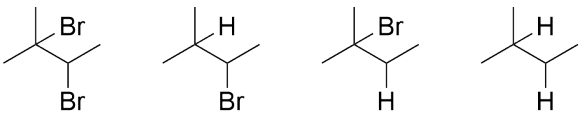
8.5 What is the correct name of the following compound? 1.0pt



A) (*Z*)-2-ethyl-4-butylhex-3,5-dienal
B) (*Z*)-2-ethyl-4-(propen-2-yl)oct-3-enal
C) (*Z*)-3-butyl-2-methylhept-1,3-diene-5-carbaldehyde
D) (*Z*)-4-butyl-2-ethylhex-3,5-dienal
E) (*Z*)-3-formyl-5-(propen-2-yl)non-4-ene

8.6 What is the major product of the following reaction? 1.0pt





A B C D