# $17^{th}$ Swiss and Liechtenstein Chemistry Olympiad

## First round

| | | |
|---|---|---|
| **Multiple Choice** | **:** | **47 Questions** |
| Duration | : | 40 minutes |
| Questions | : | - Multiple Choice Questions (MC)<br>- Multiple True False Questions (MTF) |
| Grading | : | Each fully correct reply is worth one point. |
| Aids and tools | : | All aids are allowed (Text books, calculators, periodic table, etc.). However, the test has to be solved on one's own without the help from others. |
| Participation conditions (according to IChO) | : | - born on or after $1^{st}$ of Juli 2003<br>- not yet immatriculated at an university<br>- attending a Swiss school (now or previously) |
| Due date | : | $14^{th}$ of October 2022 |
| Due address | : | Wissenschafts-Olympiade<br>Universität Bern<br>Hochschulstrasse 6<br>3012 Bern |

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

# Good luck!

## General Questions

### Question 1 (MC):

What mass of $CuSO_4$ is needed to produce 0.6 L of a 0.25 mol $L^{-1}$ solution of $CuSO_4$?

A 9.91 g

B 23.94 g

C 47.88 g

D 95.77 g

### Question 2 (MC):

Which element has the largest atomic radius?

A Li

B Be

C N

D O

### Question 3 (MC):

Which bond is the most polar?

A N-H

B O-H

C C-O

D C-H

### Question 4 (MC):

Which electronic configuration of a ground-state corresponds to the most electropositive neutral element?

A $(3s)^1$

B $(3s)^2(3p)^3$

C $(3s)^2$

D $(3s)^2(3p)^5$

### Question 5 (MC):

Which molecule does <u>not</u> contain 6 carbon atoms?

A 1,2-dichloro-3-methylpentane

B 2,2-dimethylpropanoic acid

C 4-methylpent-1-ene

D 1,2-dimethylcyclobutane

### Question 6 (MC):

Which of these molecules contains an atom other than H for which the octet rule is <u>not</u> satisfied?

A $H_2CO_3$

B $BF_3$

C $NH_3$

D $CBr_4$

### Question 7 (MC):

The pH value of a $10^{-9}$ mol $L^{-1}$ solution of HCl is:

A Below 5

B Between 6 and 7

C About 9

D Above 10

### Question 8 (MC):

What kind of reaction is the following equation?

$$3\,Na_2O + 2\,H_3PO_4 \longrightarrow 2\,Na_3PO_4 + 3\,H_2O$$

A Redox reaction

B Neutralisation

C Precipitation

D Condensation

## Metathesis

When mixing equal parts of a 1.0 mol $L^{-1}$ solution of $Na_3PO_4$ and a 0.5 mol $L^{-1}$ solution of $Fe_2(SO_4)_3$, an insoluble product is formed and filtered off.

### Question 9 (MTF):

The insoluble product contains:

A $PO_4^{3-}$

B $Na^+$

C $SO_4^{2-}$

D $Fe^{3+}$

## Question 10 (MC):

The insoluble product is:

A Colourless to pale yellow
B Reddish brown in colour
C Green in colour
D A different colour

## Question 11 (MTF):

The mother liquor contains:

A $Fe^{3+}$
B $PO_4{}^{3-}$
C $SO_4{}^{2-}$
D $Na^+$

## Question 12 (MC):

Evaporation of the mother liquor gives:

A A neutral solid
B An acidic substance
C An oxide
D A different substance

## Titration

100 mL of a 0.01 mol L$^{-1}$ formic acid solution is titrated with 0.02 mol L$^{-1}$ NaOH. For formic acid $pK_a = 3.75$.

## Question 13 (MC):

Formic acid has the sum formula:

A HCOOH
B $C_6H_5OH$
C HF
D None of the above

## Question 14 (MC):

Formic acid is:

A A strong acid
B A strong base
C A weak acid
D None of the above

## Question 15 (MC):

A 0.01 mol L$^{-1}$ solution of formic acid has a pH value of:

A 2.00
B 2.87
C 3.75
D None of the above

## Question 16 (MC):

What is the reaction equation for this titration?

A $HCOOH + NaOH \longrightarrow HCOONa + H_2O$
B $HCOOH + 2\,NaOH \longrightarrow Na_2COO + 2\,H_2O$
C $2\,HCOOH + NaOH \longrightarrow NaH(HCOO)_2 + H_2O$
D None of the above

## Question 17 (MC):

What volume of 0.02 mol L$^{-1}$ NaOH is needed to get a final pH value of 3.75?

A 0 mL
B 50 mL
C 100 mL
D 25 mL

## Question 18 (MC):

What is the concentration of final product in the solution when the acid is entirely neutralised (no excess of base)?

A 0.01 mol L$^{-1}$
B 0.02 mol L$^{-1}$
C 0.0067 mol L$^{-1}$
D None of the above

## Question 19 (MC):

What is the pH of the solution when the acid is entirely neutralised (no excess of base)?

A 7.00
B 7.50
C 7.83
D None of the above

### Question 20 (MC):

What is the pH obtained in the titration if 1.00 L of 0.01 mol $L^{-1}$ NaOH is added to the initial formic acid solution?

A About 7
B About 12
C About 14
D None of the above

## Chemistry of the Elements

### Question 21 (MTF):

$NO_2$ is an unusual molecule because:

A Its N atom does not respect the octet rule
B It is decomposed by water
C Its oxygen atom does not respect the octet rule
D It has an unpaired electron

### Question 22 (MTF):

Which of the following substances make(s) a basic solution in water?

A $NH_4Cl$
B CaO
C $AlCl_3$
D $CH_3COONa$

### Question 23 (MTF):

Which of the following substances can react with one another in aqueous solution?

A $H_2 + Cl_2$
B $H_2 + Cu^{2+}$
C $Ag + Cu^{2+}$
D $Zn + Cu^{2+}$

### Question 24 (MTF):

During the electrolysis of $CuCl_2$ in aqueous solution, which of the following happens?

A Hydrogen bubbles may form at the anode
B The metal is oxidised at the cathode
C Oxygen bubbles may form at the anode
D Chlorine bubbles may form at the anode

### Question 25 (MC):

Black powder is a mixture of potassium nitrate ($KNO_3$), charcoal (C), and sulfur (S). Its decomposition occurs according to the following reaction equation:

$$2\,KNO_3 + 3\,C + S \longrightarrow K_2S + 3\,CO_2 + N_2$$

Which element undergoes the biggest change in oxidation state?

A Sulfur
B Potassium
C Carbon
D Nitrogen

### Question 26 (MC):

Black powder is a mixture of potassium nitrate ($KNO_3$), charcoal (C), and sulfur (S). Its decomposition occurs according to the following reaction equation:

$$2\,KNO_3 + 3\,C + S \longrightarrow K_2S + 3\,CO_2 + N_2$$

What proportion of the initial mass is lost as a gas after the reaction has occurred?

A 60%
B 85%
C 50%
D 100%

### Question 27 (MC):

Pyrite is a mineral with sum formula $FeS_2$, which burns in air to give iron(III) oxide and sulfur dioxide. What is the stoichiometric coefficient of $O_2$ when the reaction equation is balanced?

A 5
B 8
C 11
D None of the above

## Question 28 (MC):

Pyrite is a mineral with sum formula $FeS_2$, which burns in air to give iron(III) oxide and sulfur dioxide. How many moles of oxygen are required to fully combust 1.2 kg pyrite?

A 11 mol

B 27.5 mol

C 44 mol

D None of the above

## Chemical Kinetics

Nitrogen(II) oxide (nitrogen monoxide) reacts with hydrogen according to the following reaction equation:

$$2\,NO\ (g) + 2\,H_2\ (g) \longrightarrow N_2\ (g) + 2\,H_2O\ (g)$$

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

| Expe-riment | Initial [NO] / mol dm$^{-3}$ | Initial [$H_2$] / mol dm$^{-3}$ | Initial reaction rate / mol$_{N_2}$ dm$^{-3}$ s$^{-1}$ |
|---|---|---|---|
| 1 | 0.100 | 0.100 | 2.53*10$^{-6}$ |
| 2 | 0.100 | 0.200 | 5.05*10$^{-6}$ |
| 3 | 0.200 | 0.100 | 10.10*10$^{-6}$ |
| 4 | 0.300 | 0.100 | 22.80*10$^{-6}$ |

## Question 29 (MC):

What is the reaction order with respect to NO and with respect to $H_2$?

A 1st order for NO, 2nd order for $H_2$

B 1st order for both

C 2nd order for NO, 1st order for $H_2$

D 2nd order for both

## Question 30 (MC):

What is the rate law for this reaction?

A $v = k[N_2][H_2O]$

B $v = k[N_2]^2[H_2]$

C $v = k[NO]^2[H_2]$

D $v = k[NO][H_2O]$

## Question 31 (MC):

What is the value of the reaction rate constant?

A 0.0506 dm$^{6}$ mol$^{-2}$ s$^{-1}$

B 2.53 dm$^{6}$ mol$^{-2}$ s$^{-1}$

C 0.0253 dm$^{6}$ mol$^{-2}$ s$^{-1}$

D 0.000253 dm$^{6}$ mol$^{-2}$ s$^{-1}$

## Solubility

Urinary (or renal) lithiasis is a condition characterised by the formation of small crystalline accretions called "kidney stones". These "stones" are mainly made up of calcium oxalate ($CaC_2O_4$) crystals. Knowing that the $K_S$ value of this salt is 2.3*10$^{-9}$:

## Question 32 (MC):

What is the correct expression of the ion product of the species in solution?

A $Q_S = \frac{[Ca^{2+}][C_2O_4{}^{2-}]}{[CaC_2O_4][H_2O]}$

B $Q_S = [CaC_2O_4]$

C $Q_S = [Ca^{2+}][C_2O_4{}^{2-}]$

D $Q_S = \frac{[Ca^{2+}][C_2O_4{}^{2-}]}{[CaC_2O_4]}$

### Question 33 (MC):

What is the minimum volume of aqueous solution required to solubilise a pure calcium oxalate kidney stone weighing 768 mg?

A 125 L

B 1250 L

C 1.25 L

D 250 L

### Question 34 (MC):

In a patient's urine sample, oxalate ($C_2O_4{}^{2-}$) is found in a concentration of 2.5*10$^{-6}$ mol L$^{-1}$ and calcium ($Ca^{2+}$) in a concentration of 5.0*10$^{-4}$ mol L$^{-1}$. Is there a risk of precipitation of a kidney stone in this patient?

A $Q_S > K_S$, so no

B $Q_S < K_S$, so yes

C $Q_S > K_S$, so yes

D $Q_S < K_S$, so no

## Thermodynamics

The standard formation enthalpies for D-glucose, $CO_2$ and $H_2O$ are -1271 kJ mol$^{-1}$, -393.6 kJ mol$^{-1}$ and -285.8 kJ mol$^{-1}$ respectively.

### Question 35 (MC):

Which reaction equation correctly describes the combustion of D-glucose?

A $2\,C_{11}H_{12}N_2O_2 + 23\,O_2 \longrightarrow 8\,H_2O + 20\,CO_2 + 2\,CH_4N_2O$

B $6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$

C $C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$

D $C_3H_6O_3 + 3\,O_2 \longrightarrow 3\,CO_2 + 3\,H_2O$

### Question 36 (MC):

What is the standard reaction enthalpy for the combustion of D-glucose?

A -5081.6 kJ mol$^{-1}$

B -2540.8 kJ mol$^{-1}$

C -2805.4 kJ mol$^{-1}$

D +2540.8 kJ mol$^{-1}$

### Question 37 (MC):

How is this reaction thermodynamically classified?

A Exothermic

B Endothermic

C Neither exo- nor endothermic

D Impossible to say based on the data

### Question 38 (MC):

To what temperature can 500 g of water be heated, starting at 25°C, by burning an excess of D-glucose with 2.00 L of pure oxygen at standard conditions, knowing that 70% of the reaction enthalpy is released as heat?

A 12.6°C

B 37.6°C

C 50°C

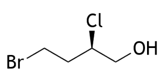
D 298 K

## Organic Chemistry

### Question 39 (MC):

What is the correct absolute configuration of the asymmetric carbons in the following molecules?

1

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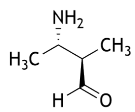


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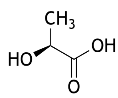



A 1: *R*, 2: *R* for C-$NH_2$ and *R* for C-$CH_3$, 3: *R*

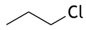
B 1: *R*, 2: *S* for C-$NH_2$ and *R* for C-$CH_3$, 3: *S*

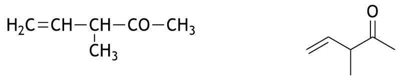
C 1: *S*, 2: *S* for C-$NH_2$ and *R* for C-$CH_3$, 3: *R*

D 1: *S*, 2: *S* for C-$NH_2$ and *S* for C-$CH_3$, 3: *S*

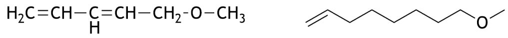
## Question 40 (MTF):

Which of the following pairs of structures describes the same molecule?

A) $H_3C-CH_2-CH_2-CH_2-Cl$ 

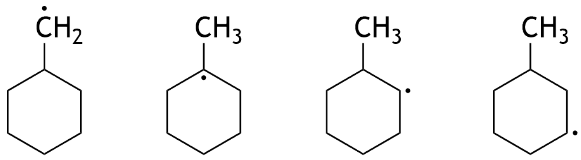
B) 

C) 

D) 

## Question 41 (MC):

Which of the following structures shows the most stable radical?



A) B) C) D)

## Question 42 (MC):

Compared to its parent alkane, an alkyl radical contains:

A One carbon atom less

B One hydrogen atom less

C One carbon atom more

D One hydrogen atom more

## Question 43 (MC):

When naming $n$-alkanes, the stem name indicates the number of:

A Hydrogen atoms

B Carbon atoms

C Oxygen atoms

D Bonds

## Question 44 (MC):

Alcohols are characterized by the formal attachement of:

A An H atom to a hydrocarbon chain

B An HX group to a hydrocarbon chain

C An O atom to the hydrocarbon chain

D An OH group to a hydrocarbon chain

## Question 45 (MC):

The general formula for amines is:

A $R_2$-CH

B R-COOH

C R-$CH_2$

D R-$NH_2$

## Question 46 (MC):

An alkane with the sum formula $C_7H_{16}$ is called:

A Butane

B Pentane

C Hexane

D Heptane

## Question 47 (MC):

Ethers are formed by the attachment of:

A Two alkyl groups to the same oxygen atom

B Two alkyl groups to different oxygen atoms

C Three alkyl groups to one oxygen atom

D Four alkyl groups to one oxygen atom