16^{th} Swiss and Liechtenstein Chemistry Olympiad

First round

Multiple Choice	**:**	**32 Questions**
Duration	:	40 minutes
Questions	:	- Multiple Choice Questions (MC) - 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 2002 - not yet immatriculated at an university - attending a Swiss school (now or previously)
Due date	:	9^{th} of October 2021
Due address	:	Wissenschafts-Olympiade Universität Bern Hochschulstrasse 6 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!

Question 1 (MC):

What is the pH of an aqueous solution of 0.67 $\frac{mol}{L}$ HCl ($pK_a(HCl) \simeq$ -6)?

A 0.67

B 13.1

C 0.17

D -6.3

E 0.63

Question 2 (MC):

Calculate the pH of an aqueous solution of 2 $\frac{mol}{L}$ acetic acid ($pK_a(AcOH) = 4.76$).

A 2.38

B 4.76

C 2.46

D 2.23

E -3.0

Question 3 (MC):

Determine the oxidation number of all atoms in the following molecule: $HCO_3{}^-$

A H: +1 / C: -4 / O: +2, 0

B H: +1 / C: +2 / O: -1

C H: +1 / C: +4 / O: -2

D H: -1 / C: -4 / O: +2, 0

E H: -1 / C: +2 / O: -2

Question 4 (MC):

Which is the right order representing the strength of the following acids:
HBr, HI, HCl, HF?

A HI > HBr > HCl > HF

B HI > HCl > HF > HBr

C HCl > HF > HBr > HI

D HF > HCl > HI > HBr

E HF > HCl > HBr > HI

Question 5 (MC):

Determine the right stoichiometric coefficients for the following reaction:
$n\,Al(OH)_3 + m\,H_2SO_4 \rightarrow x\,Al_2(SO_4)_3 + y\,H_2O$

A n: 2, m: 3, x: 1, y: 6

B n: 2, m: 6, x: 2, y: 6

C n: 1, m: 3, x: 1, y: 3

D n: 1, m: 6, x: 1, y: 3

E n: 2, m: 6, x: 1, y: 3

Question 6 (MC):

Determine the right stoichiometric coefficients for the following reaction:
$a\,Na_2[B_4O_7] + b\,SiO_2 + c\,Na + d\,H_2 \rightarrow x\,NaBH_4 + y\,Na_2SiO_3$

A a: 2 , b: 7 , c: 16 , d: 16

B a: 1 , b: 7 , c: 16 , d: 8

C a: 1 , b: 7 , c: 16 , d: 16

D x: 8 , y: 1

E x: 1 , y: 1

Question 7 (MC):

How much $PbSO_4$ ($K_L = 2.53 \cdot 10^{-8}\ \frac{mol^2}{L^2}$) can be dissolved in 2L of water?

A 0.096 g

B 0.068 g

C 0.048 g

D $5.06 \cdot 10^{-6}$ mol

E $5.06 \cdot 10^{-8}$ mol

Question 8 (MC):

The yield of the following reaction is 20 % at 2 bars and 290 K, what happens if we increase the pressure?
$CO_2 + KOH \rightleftharpoons KHCO_3$

A The yield increases

B The reaction goes to completion

C Nothing

D No Product at all is formed

E The yield decreases

Question 9 (MC):

Calculate the volume of 0.4 moles of PH_3 at 31°C and 1.5 bars.

A 6.44 m^3
B 148 m^3
C 6.74 L
D 0.69 L
E $6.87 \cdot 10^{-4}\,m^3$

Question 10 (MC):

Calculate the energy of one photon at 460 nm.

A $4.32 \cdot 10^{-8}\,kJ$
B $4.32 \cdot 10^{-8}\,J$
C $9.13 \cdot 10^{-32}\,kJ$
D $4.32 \cdot 10^{-19}\,J$
E $3.04 \cdot 10^{-31}\,J$

Question 11 (MC):

Which is the correct expression for the equilibrium constant of the following reaction?
$4\,NH_3 + 5\,O_2 \rightleftarrows 4\,NO + 6\,H_2O$

A $K = \frac{[NO]^{-4}[H_2O]^{-6}}{[NH_3]^4[O_2]^5}$
B $K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$
C $K = \frac{[NH_3][O_2]}{[NO][H_2O]}$
D $K = \frac{[NH_3]^4[O_2]^5}{[NO]^4[H_2O]^6}$
E $K = \frac{[NO][H_2O]}{[NH_3][O_2]}$

Question 12 (MC):

Calculate the combustion enthalpy of propane (the reaction of C_3H_8 with oxygen):
$\Delta_f H(CO_2)$ = -393.5 kJ/mol
$\Delta_f H(H_2O)$ = -241.8 kJ/mol
$\Delta_f H(C_3H_8)$ = -104.0 kJ/mol

A $\Delta_c H$ = -2043.7 kJ/mol
B $\Delta_c H$ = -2251.7 kJ/mol
C $\Delta_c H$ = -3288.7 J/mol
D $\Delta_c H$ = -3288.7 kJ/mol
E $\Delta_c H$ = 2043.7 kJ/mol

Question 13 (MC):

Which percentage of a ^{212}Bi sample has decayed after 5 min ($t_{1/2}$ = 3633 s)?

A 0.1 %
B 50 %
C 5.6 %
D 94 %
E 9.1 %

Question 14 (MC):

Which is the correct equation for an alpha decay of ^{235}U?

A $^{235}U \rightarrow {}^{231}Th^{2-} + {}^{4}He^{2+}$
B $^{235}U \rightarrow {}^{231}Th + {}^{4}He^{2+}$ + energy
C $^{235}U \rightarrow {}^{231}Th + {}^{4}He$
D $^{235}U \rightarrow {}^{231}Th + {}^{4}He$ + energy
E $^{235}U \rightarrow {}^{231}Th^{2-} + {}^{4}He^{2+}$ + energy

Question 15 (MC):

In which mode of radioactive decay does ^{99}Tc decay into $^{99}Ru^{+}$?

A Alpha decay
B Beta minus decay
C Electron capture
D Gamma decay
E Beta plus decay

Question 16 (MC):

The transmission of a 0.3 molar solution of Sudan II (a red dye) is 0.2 at a wavelength of 500 nm and a width of 1 cm. Calculate the molar extinction coefficient at 500 nm.

A 2.33 $\frac{L}{mol \cdot cm}$
B 5.36 $\frac{L}{mol \cdot cm}$
C 0.67 $\frac{L}{mol \cdot cm}$
D 10.01 $\frac{L}{mol \cdot cm}$
E 0.0067 $\frac{L}{mol \cdot cm}$

Question 17 (MC):

The combustion of one mole of an organic substance with 4.5 equivalents of oxygen produces solely 72 g H_2O and 132 g CO_2. What is the sum formula of the organic substance?

A C_4H_6O

B $C_3H_8O_2$

C C_3H_8O

D $C_4H_8O_2$

E C_3H_8

Question 18 (MC):

Which of the following molecules contains a mass percentage of phosphorous of 66 % and a mass percentage of oxygen of 34 %?

A PO_2

B P_4O_{10}

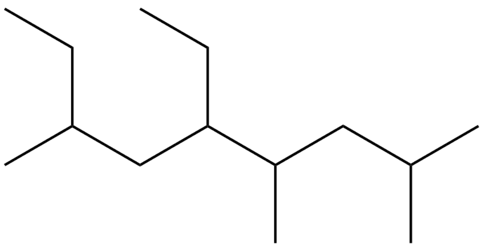
C P_4O_6

D P_2O_2

E P_3O_4

Question 19 (MC):

According to IUPAC, what ist the name of the following compound?



A 5-ethyl-2,4,7-trimethylnonane

B 2,4-diethyl-5,7-dimethyloctane

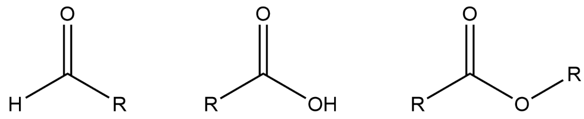
C 5-ethyl-3,6,8-trimethylnonane

D 5,7-diethyl-2,4-dimethylnonane

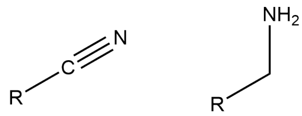
E 5,7-diethyl-2,4-dimethyloctane

Question 20 (MTF):

Which assignments are true?



I **II** **III**



IV **V**

A II carboxylic acid

B I ketone

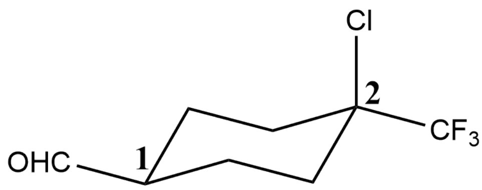
C V amide

D IV nitrile

E III ether

Question 21 (MC):

Which ones are the right stereoindicators of this compound?



A 1R / 2R

B 1S / 2S

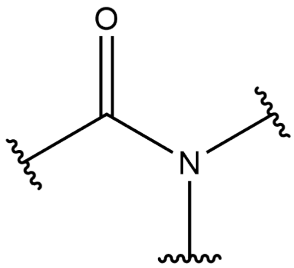
C 1R / 2S

D This compound has no chiral centers.

E 1S / 2R

Question 22 (MC):

How many isomers are composed of C_4H_7ON and contain the following motif? (Hint: As you can see in the figure, no double bonds to the nitrogen are allowed)



A 17

B 12

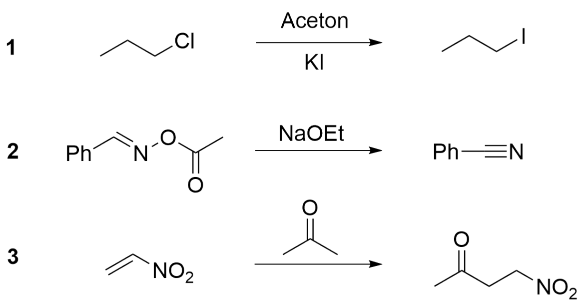
C >19

D 7

E 3

Question 23 (MC):

What are the reaction types of the following reactions?



A 1 – Elimination / 2 – Elimination / 3 – Substitution

B 1 – Substitution / 2 – Elimination / 3 – Addition

C 1 – Addition / 2 – Elimination / 3 – Substitution

D None of these options.

E 1 – Addition / 2 – Substitution / 3 – Elimination

Question 24 (MC):

Which is the correct order regarding the boiling points of these substances?

A *n*-butane < propane < 1-butanol < *tert*-butyl alcohol < butyric acid

B propane < *n*-butane < *tert*-butyl alcohol < 1-butanol < butyric acid

C propane < *n*-butane < butyric acid < *tert*-butyl alcohol < 1-butanol

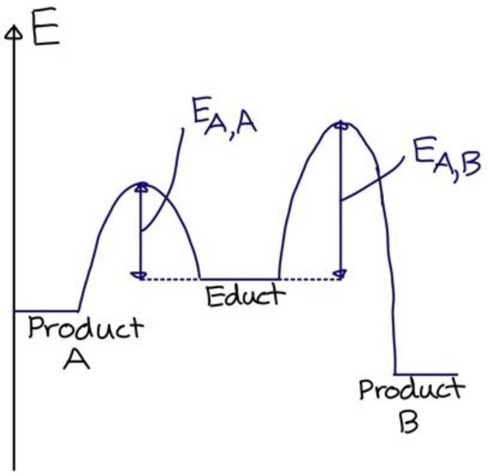
D *n*-butane < propane < *tert*-butyl alcohol < 1-butanol < butyric acid

E propane < *n*-butane < 1-butanol < *tert*-butyl alcohol < butyric acid

Question 25 (MC):

How many of the following statements are true (see Figure below)?

- For the energy E given to the system with boundaries $E_{A,A} < E < E_{A,B}$, the major product is A.
- When the energy given to the system $E >> E_{A,B}$ the major product is A.
- When the energy given to the system $E = E_{A,A}$ the major product is B.
- When the energy given to the system $E >> E_{A,B}$ the major product is B.
- A catalyst that favours the reaction to product B, lowers the free energy of product B.
- A catalyst does not change the free energy of product A.
- In general, a catalyst increases the activation energy.



A 5

B 4

C 6

D 3

E 2

Question 26 (MTF):

Mark the correct statements (everything refers to the periodic table of elements).

A The electronegativity increases from the bottom left to the upper right.

B The size of atoms decreases from bottom to top.

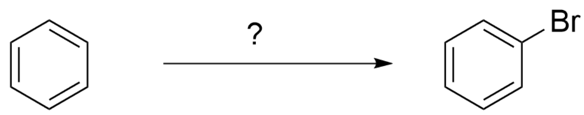
C The size of the atoms increases from the left to the right.

D The ionisation energy increases from upper right to bottom left.

E The number of valence electrons increases from the left to right.

Question 27 (MC):

What reactant(s) is/are needed for this reaction?



A $CHBr_3$

B Br_2 / $FeBr_3$

C HBr / H_2O

D This reaction is impossible.

E LiBr / NaBr (1:1)

Question 28 (MC):

Which of the following salts has the highest absolute lattice energy? (Hint: Consider the strenght of the ionic interaction)

A LiF

B NaBr

C CaO

D MgO

E NaCl

Question 29 (MTF):

Which molecule(s) contain(s) a permanent dipole?

A $(CH_3)_2CO$ (acetone)

B CH_4

C CO_2

D H_2O

E ${CO_3}^{2-}$

Question 30 (MC):

What is the name of $[Pt(NH_3)_4]Cl_2$?

A Platinum(II) tetramino dichloride

B Dichloride tetraaminoplatinum(II)

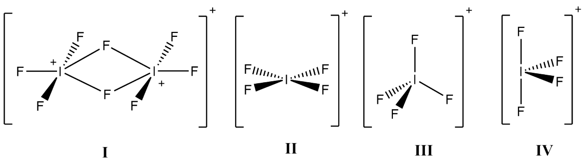
C Dichlorotetraamonium platinum

D Dichloro tetraaminoplatinum

E Tetraaminoplatinum(II) chloride

Question 31 (MC):

What is the right geometry of ${IF_4}^{+}$?



A II

B IV

C This molecule doesn't exist.

D I

E III

Question 32 (MC):

Which of these statements is true?

A If the activation energy increases, the reaction deccalerates and less product is formed in equilibrium.

B If the activation energy increases, the reaction accalerates and more product is formed in equilibrium.

C The activation energy only has an effect on the product formation and not on the formation of the educt in an equilibrium.

D The activation energy does not have an effect on the reaction rate and the product formation in equilibrium

E The activation energy only has an effect on the reaction rate.