CHIMIESOLYMPIAD
LËTZEBUERG 2020

QUALIFICATION ROUND

Dear students,

Congratulations for participating in the Chemistry Olympiad ! We wish you every success in this event as well as in your studies and in all your future endeavours.

Before beginning this test, read the following carefully.

IMPORTANT NOTES

- You must answer 17 questions for a total of 100 points.
- **Follow the instructions carefully.**
- You have, at the beginning of the questionnaire, a page with a table of the relative atomic masses of the elements, the value of some constants as well as the electronegativities of the elements of the first three periods.
- At the end of the questionnaire, you will have a draft sheet of paper to make notes and calculations and to prepare your answers.
- The duration of the test is 2 hours.
- The use of a non-programmable calculator is allowed.
- To facilitate student work, the indication of aggregation states is not required.

In several questions, you will have to make a choice between two or more answers. In this case, simply mark the number(s), the letter(s) or check the box(es) corresponding to the correct answer(s) in a very visible manner.

The candidates selected at the end of this first round will be summoned to the second event of the National Olympiad which will take place on Thursday, March 12, 2020 at 14:30 at the Robert-Schuman High School in Luxembourg.

At the end of this second event, a dozen national winners will be chosen to participate in the final, which will take place on Saturday, April 25th.

This last event will select, among them, the four students who will participate in the 52nd IChO in Istanbul, from July 6 to 15, 2020. More information can be found on http://icho.olympiades.lu/.

Wishing you good luck.
The organizers of the Chemistry Olympiad

Detach this sheet and keep it for your information.

Natural constants

(You may detach this sheet if necessary)

LIÈGE université

TABLEAU PÉRIODIQUE DES ÉLÉMENTS

masse atomique relative	A_r	
	X	élément
nombre atomique	Z	

1 I a	2 II a		3 III b	4 IVb	5 V b	6 VI b	7 VII b	8	9 VIII b	10	11 I b	12 II b	13 III a	14 IV a	15 V a	16 VI a	17 VII a	18 VIII a
1,01 H 1																		4,00 He 2
6,94 Li 3	9,01 Be 4												10,81 B 5	12,01 C 6	14,01 N 7	16,00 O 8	19,00 F 9	20,18 Ne 10
22,99 Na 11	24,31 Mg 12												26,98 Al 13	28,09 Si 14	30,97 P 15	32,07 S 16	35,45 Cl 17	39,95 Ar 18
39,10 K 19	40,08 Ca 20		44,96 Sc 21	47,88 Ti 22	50,94 V 23	52,00 Cr 24	54,94 Mn 25	55,85 Fe 26	58,93 Co 27	58,69 Ni 28	63,55 Cu 29	65,39 Zn 30	69,72 Ga 31	72,61 Ge 32	74,92 As 33	78,96 Se 34	79,90 Br 35	83,80 Kr 36
85,47 Rb 37	87,62 Sr 38		88,91 Y 39	91,22 Zr 40	92,91 Nb 41	95,94 Mo 42	Tc* 43	101,07 Ru 44	102,91 Rh 45	106,42 Pd 46	107,87 Ag 47	112,41 Cd 48	114,82 In 49	118,71 Sn 50	121,75 Sb 51	127,60 Te 52	126,90 I 53	131,29 Xe 54
132,91 Cs 55	137,33 Ba 56	(1) 57 - 70	174,97 Lu 71	178,49 Hf 72	180,95 Ta 73	183,9 W 74	186,21 Re 75	190,21 Os 76	192,22 Ir 77	195,08 Pt 78	196,97 Au 79	200,59 Hg 80	204,38 Tl 81	207,21 Pb 82	208,98 Bi 83	Po* 84	At* 85	Rn* 86
Fr* 87	Ra* 88	(2) 89 - 102	Lr* 103	Rf* 104	Db* 105	Sg* 106	Bh* 107	Hs* 108	Mt* 109	Ds* 110	Rg* 111	Cn* 112	Nh* 113	Fl* 114	Mc* 115	Lv* 116	Ts* 117	Og* 118

1) Lanthanides	138,92 La 57	140,12 Ce 58	140,91 Pr 59	144,24 Nd 60	Pm* 61	150,36 Sm 62	151,97 Eu 63	157,25 Gd 64	158,93 Tb 65	162,50 Dy 66	164,93 Ho 67	167,26 Er 68	168,93 Tm 69	173,04 Yb 70
2) Actinides	Ac* 89	232,04 Th 90	231,04 Pa 91	238,03 U 92	Np* 93	Pu* 94	Am* 95	Cm* 96	Bk* 97	Cf* 98	Es* 99	Fm* 100	Md* 101	No* 102

* Elements which don't have any isotopes with a sufficiently long half-life and thus don't have a characteristic terrestrial composition.

Constants

$R = 8{,}31\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

$R = 8{,}21 \cdot 10^{-2}\ \mathrm{L \cdot atm \cdot mol^{-1} \cdot K^{-1}}$

Volume of one mole of an ideal gas at 273 K and 101 325 Pa : 22,4 $\mathrm{dm^3\ mol^{-1}}$ ($\mathrm{L \cdot mol^{-1}}$)

$1\ F = 9{,}65 \cdot 10^4\ \mathrm{C \cdot mol^{-1}}$

$N_A = 6{,}02 \cdot 10^{23}\ \mathrm{mol^{-1}}$

1atm = 760 mmHg = 101325 Pa

Electronegativities of the elements found in the first 3 periods

H :	2,1	N :	3,0	Al :	1,5
Li :	1,0	O :	3,5	Si :	1,8
Be :	1,5	F :	4,0	P :	2,1
B :	1,9	Na :	0,9	S :	2,5
C :	2,5	Mg :	1,2	Cl :	3,0

Chemistry OLYMPIAD 2020

QUALIFICATION ROUND

Name : ______________________________

First name : ______________________________

School : ______________________________

4 pts | **QUESTION I – Air**

4 pts

Complete the table by indicating the 4 main constituents of "natural and dry" air, giving their name and formula. Then indicate by a cross in the appropriate column(s), which constituent:

- is responsible for the slightly acidic nature of water, even distilled, in contact with air;
- is essential for the breathing of all living beings;
- is essential for photosynthesis in green plants;
- is used in the manufacture of nitrogen fertilizers;
- is chemically inert at room temperature.

Name of the constituent	Formula	Causes acidification of water	Respiration	Photosynthesis	Fertilizer	chemically inert
Helium	*He*					*x*

Complete the above table based on the example in the first row.

4 pts | **QUESTION II – density**

The following gases are considered:

A: Nitric oxide
B: Chlorine
C: Argon
D: Hydrogen
E: Nitrogen
F : Oxygen

2 pts

1) Put the 6 gases in order of density in standard temperature and pressure.

a) D < E < A < F < C < B b) D < A < E < F < C < B c) D < E < A < F < B < C

2 pts

2) What will happen to the density of argon if the temperature is changed to 819K and the pressure to 3 atm ?

a) It will triple.
b) It increases by a factor of 9
c) It doesn't change.
d) It reduces by a factor of 3
e) It reduces by a factor of 9

Circle the correct response

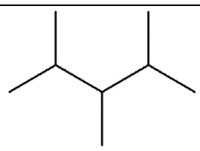
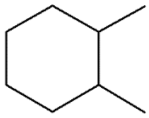
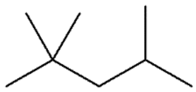
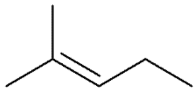
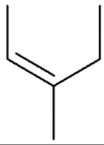
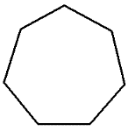
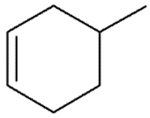
10 pts	QUESTION III – Combustion of diesel
	The average molecular formula for diesel fuel can be considered to be $C_{12}H_{26}$. Dodecane ($C_{12}H_{26}$.) has a combustion enthalpy of -8072 kJ·mol^{-1} and a density of 0.745 g·mL^{-1}. The enthalpy of combustion of a given substance is defined as the change in enthalpy for the reaction of one mole of substance with oxygen to form carbon dioxide gas and liquid water.
2 pts	We can consider that the average molecular formula of diesel fuel is $C_{12}H_{26}$. 1) Write and balance the chemical equation corresponding to the complete combustion of dodecane:
4 pts	2) Calculate in kJ the amount of heat released during the complete combustion of a litre of diesel, assuming that it is dodecane. a) 17,7·10^3 kJ b) 1,81·10^3 kJ c) 25,6·10^3 kJ d) 35,4·10^3 kJ e) 70,8·10^3 kJ
4 pts	3) What is the mass of carbon dioxide produced when 15,000 kJ of energy is generated? a) 1385 g b) 692 g c) 645 g d) 81,6 g e) 981 g *Circle the correct answer*

5 pts	QUESTION IV – Coca Cola and Phosphoric Acid
	Phosphoric acid is produced industrially by the action of concentrated sulfuric acid (93%) on fluoroapatite $Ca_5(PO_4)_3F$, according to the following reaction. Balance the following chemical equation. ___$Ca_5(PO_4)_3F$ + ___H_2SO_4 → ___$CaSO_4$ + ___HF + ___H_3PO_4
5 pts	Knowing that Coca-Cola contains 170 mg / L of phosphoric acid and that 1.8 billion bottles (33 cl) of this drink are produced each day, what is the mass (in tonnes) of fluoroapatite extracted and used to produce Coca-Cola in a year? a) 175 b) 2,6·10^3 c) 6,4·10^4 d) 525 e) 1,91·10^5 *Circle the correct answer*

8 pts | **QUESTION V – Isomers of hydrocarbons**

The fuels used in internal combustion engines are complex mixtures of hydrocarbons with between 4 and12 carbon atoms and many additives.

The table below contains molecules that can be found in an example of petrol

a1		a2	
b1		b2	
c1		c2	
d1		d2	

4 pts

1) For each pair, indicate whether they are isomeric molecules

	Yes	No
a) a1 et a2		
b) b1 et b2		
c) c1 et c2		
d) d1 et d2		

Place a cross in the table indicating the correct response.

8x 0.5 pt

2) Give the number of the molecule associated with the following names.

	(Z)-3-methylpent-2-ene		2,3,4-trimethylpentane
	2,2,4-trimethylpentane		cycloheptane
	1,2-dimethylcyclohexane		2-methylpent-2-ene
	n-octane		4-methylcyclohex-1-ene

Complete the table using the diagrams a1- d2 above.

5 pts | **QUESTION VI – Solubility of the chlorides of potassium**

5 pts

What mass of potassium chloride should be added to 100.0 g of an aqueous solution containing 5% (by mass) of this salt in order to obtain a saturated solution (at 20 ° C)?
The solubility of potassium chloride in water, at 20 °C, is 32,0 g per 100,0 g of H_2O.

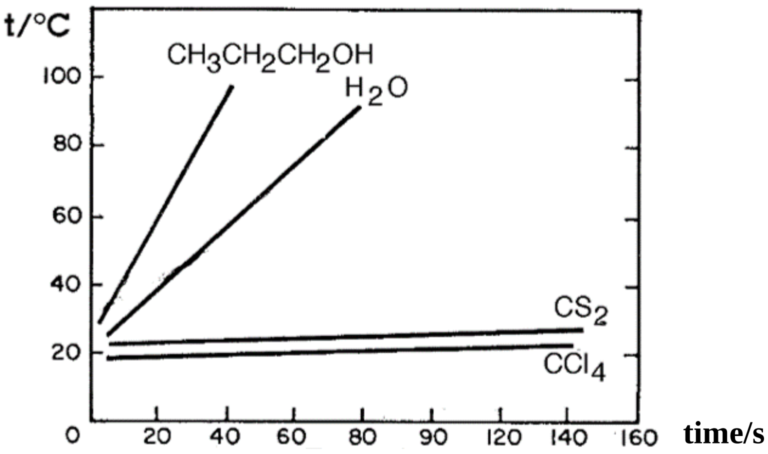
a) 0,95 g b) 5,10 g c) 25,40 g d) 27,0 g e) 30,40 g

Circle the correct response.

6 pts	**QUESTION VII – Heating in the microwave**

K.W. WATKINS studied the temperature rise experienced by different liquids in a microwave oven. He heated, for 20 second intervals, 100 mL of each of the following: CCl_4; CS_2; H_2O; *n*-C_3H_7OH; *n*-$C_{15}H_{31}COOCH_3$.

He reported the temperatures measured as a function of the heating time. The graph below shows the results obtained for the first four substances.



The table below shows data relating to the substances studied.

Substance	Molecular Mass (in g·mol^{-1})	Polarity	Specific heat capacity* (in J·g^{-1}·K^{-1})
CCl_4	153,82	Non- polar	0,86
CS_2	76,14	Non-polar	1,0
H_2O	18,01	Polar	4,18
n-C_3H_7OH	60,11	Polar	2,4

**The amount of heat energy required to heat 1 g of a sample by 1 K*

2x1 pt

1) After 40 seconds,
   a) the substance which has undergone the most significant rise in temperature is:

   b) the substance with the least significant temperature rise is substance:

Write in the chemical formulas in each case.

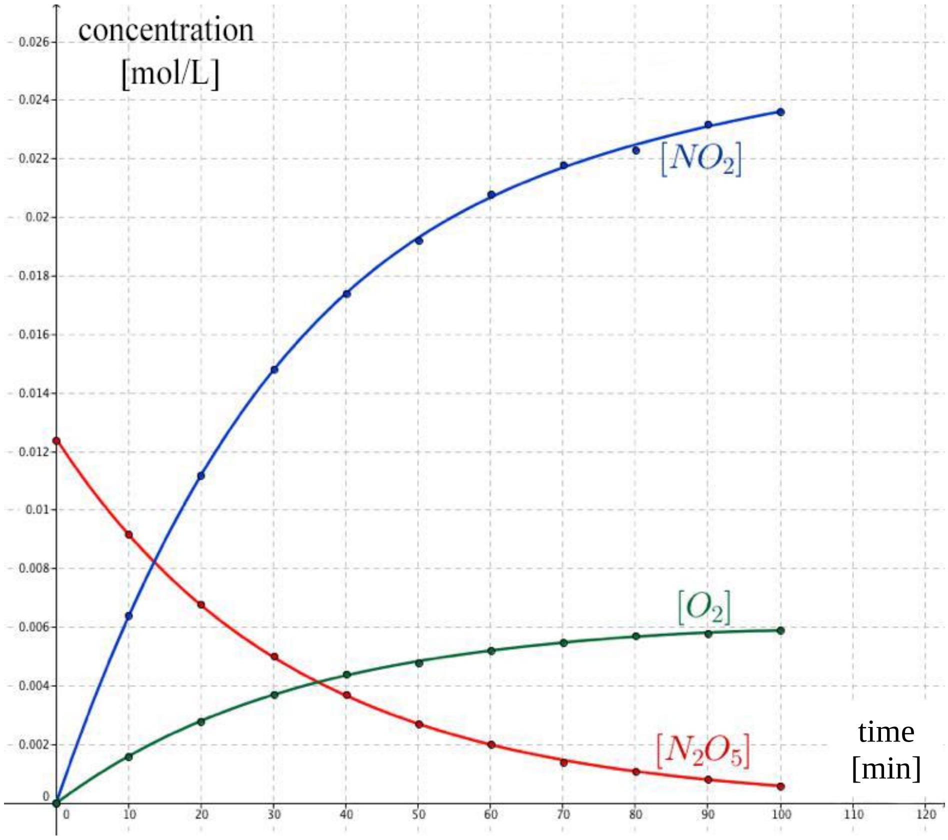
In the propositions above, what is the best explanation for the observations ?

2 pts	1) The difference in behaviour between the 4 substances is mainly explained on the basis of:	The molar mass	Polarity	Specific heat capacity
2 pts	2) The difference in behaviour between water and propan-1-ol can be explained on the basis of:	The molar mass	Polarity	Specific heat capacity

Circle the correct response in each case.

8 pts | **QUESTION VIII – Kinetics**

On studying the kinetics of a reaction, the following graph is obtained.



4 pts

1) What is the chemical equation associated with the graph above ?
   a) $O_2 + 2\ NO_2 \rightarrow N_2O_5$
   b) $N_2O_5 \rightarrow\ NO_2 + O_2$
   c) $4\ NO_2 + O_2 \rightarrow 2\ N_2O_5$
   d) $2\ N_2O_5 \rightarrow 4\ NO_2 + O_2$

2 pts

2) What is the time for the half-life of this reaction ?
   a) 100 minutes
   b) 23 minutes
   c) 36 minutes
   d) 50 minutes

Circle the correct response.

2 pts

3) Based on the information that was provided, we can say that:

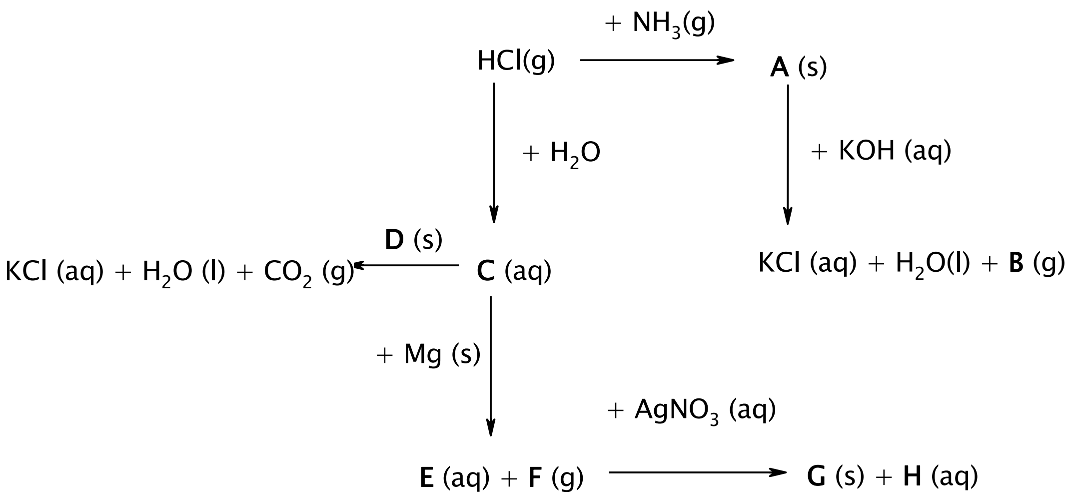
	True	False	Impossible to determine
a) The reaction uses a catalyst			
b) The reaction is exothermic			

Place a cross corresponding with the correct choice.

8 pts	**QUESTION IX – Inorganic chemistry**

Find the chemical formulas of the following compounds: A,B,C,D,E,F,G and H.

8x1 pt



A	B	C	D
E	**F**	**G**	**H**

Give the correct chemical formula for each compound.

5 pts	**QUESTION X – Manganese**

Manganese is an element which is found in various inorganic compounds and which has various oxidation states. In the series of minerals shown in the table below, calculate the oxidation number of manganese for each of the minerals and note it by means of a cross in the appropriate column.

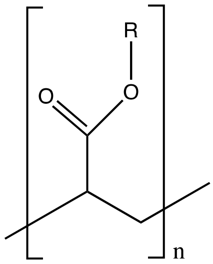
5x1 pt

	Mineral name	Chemical formula	(+II)	(+III)	(+IV)
a)	Hetaerolite	$ZnMn_2O_4$			
b)	Pyrolusite	MnO_2			
c)	Sarkinite	$Mn_2(AsO_4)(OH)$			
d)	Tephroite	Mn_2SiO_4			
e)	Rhodochrosite	$MnCO_3$			

Place a cross in the box corresponding to the correct oxidation state.

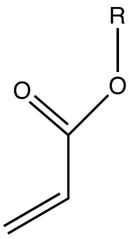
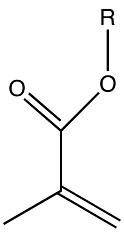
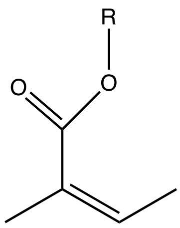
5 pts	**QUESTION XI – 3D printers**

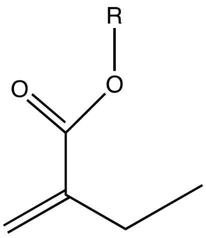
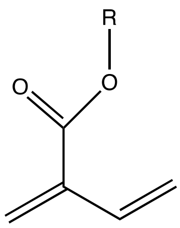
Additive manufacturing, better known as 3D printing, is an emerging technique for making parts with complex geometries. Stereolithography (SLA) is a printing technique based on light curing. Among the most commonly used polymers are polyacrylates.



3 pts

1) Choose from the following structures the one that resembles the monomer for the structure above:

a. 
b. 
c. 

d. 
e. 

1 pt

2) During photopolymerization, what functional group reacts to form the polymer?

a) Carboxylic Acid   b) Alcohol   c) Ester   d) Alkene   e) Amide

1 pt

3) What is the functional group present in polyacrylates?

a) Carboxylic acid   b) Alcohol   c) Ester   d) Alkene   e) Amide

Circle the correct response

5 pts	QUESTION XII – Rocket Fuel
5 pts	The fuel / oxidizing agent mixture consisting of N, N-dimethylhydrazine, $(CH_3)_2NNH_2$, and dinitrogen tetroxide, N_2O_4 (both in liquid form) is commonly used in the propulsion of space vehicles. The gases released during this reaction are as follows: N_2, CO_2 et H_2O. How many moles of gas are produced from 1 mole of $(CH_3)_2NNH_2$ considering a stoichiometrically balanced reaction with nitrogen tetroxide? a) 8 b) 9 c) 10 d) 11 e) 12 *Circle the correct response.*

5 pts	QUESTION XIII – ^{85}Rb
5x1 pt	Do the following atoms possess the same number of neutrons as ^{85}Rb ? *Place a cross in the box corresponding with the correct answer.*

	True	False
a) ^{85}Kr		
b) ^{87}Y		
c) ^{85}Sr		
d) ^{86}Sr		
e) ^{86}Kr		

5 pts	QUESTION XIV – Combustion of Acetone
5 pts	The complete combustion of one mole of pure acetone (C_3H_6O), in its liquid state releases 1788,92 kJ. Using the enthalpy values below, calculate the standard heat of formation $\boldsymbol{\Delta H_f^\circ}$ of liquid acetone. $\Delta H_f^\circ(H_2O, l) = -285{,}80\ kJ/mol$ $\Delta H_f^\circ(CO_2, g) = -393{,}00\ kJ/mol$ a) -138,3 kJ/mol b) -247,5 kJ/mol c) -431,3 kJ/mol d) -926,6 kJ/mol e) -3824,6 kJ/mol *Circle the correct response.*

7 pts	**QUESTION XV – Equilibrium**

The two equilibria shown below are characterised by the K_p values.

$$(1) : C_{(s)} + \tfrac{1}{2} O_{2\,(g)} \rightleftharpoons CO_{(g)} \qquad K_{p1} = 10^{24}$$
$$(2) : C_{(s)} + O_{2\,(g)} \rightleftharpoons CO_{2\,(g)} \qquad K_{p2} = 10^{69}$$

2x 0.5 pt

1) Give the K_p expression for each equilibrium:

K_{p1} =

K_{p2} =

2 pts

2) Calculate K_{p3} for the third, new, equilibrium: (3) : CO_2 (g) + C (s) ⇌ 2 CO (g)

a) 10^{45} b) 10^{-45} c) 10^{21} d) 10^{-21}

Circle the correct response.

4x1 pt

3) Using the following symbols (→, ← or X if there is no change) identify what will happen to the position of the equilibrium in each of the following scenarios.

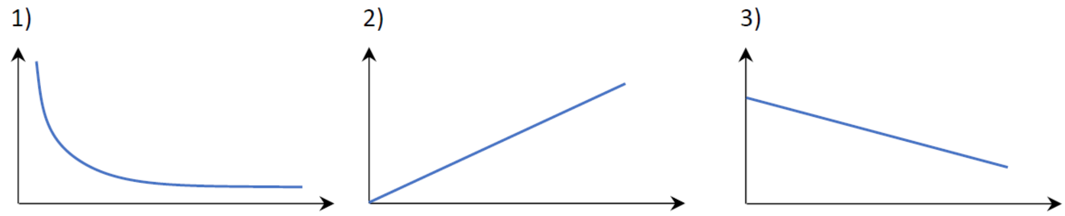
	→	←	X
a) Increase the mass of $C_{(s)}$:			
b) Increase the total pressure :			
c) Decrease the pressure of CO :			
d) Increase the temperature :			

Place a cross in the box that corresponds with the correct response.

5 pts	**QUESTION XVI – Ideal Gases**

A sample of gas is characterized by the quantities p (pressure), V (volume), T (absolute temperature), n (quantity of gas in mol).

Look at the following graphic representations



5x1 pt

	True	False
a) Graph 2 can represent p as a function of T (V and n are constant.).		
b) Graph 1 can represent T as a function of V (p and n are constant).		
c) Graph 3 can represent V as a function of p (T and n are constant).		
d) Graph 2 can represent p as a function of n (T and V are constant).		
e) Graph 1 can represent V as a function of p (T and n are constant).		

Place a cross in the box corresponding to the correct choice.

5 pts	**QUESTION XVII – Kinetics of the oxidation of iodide ions**

5x1 pt

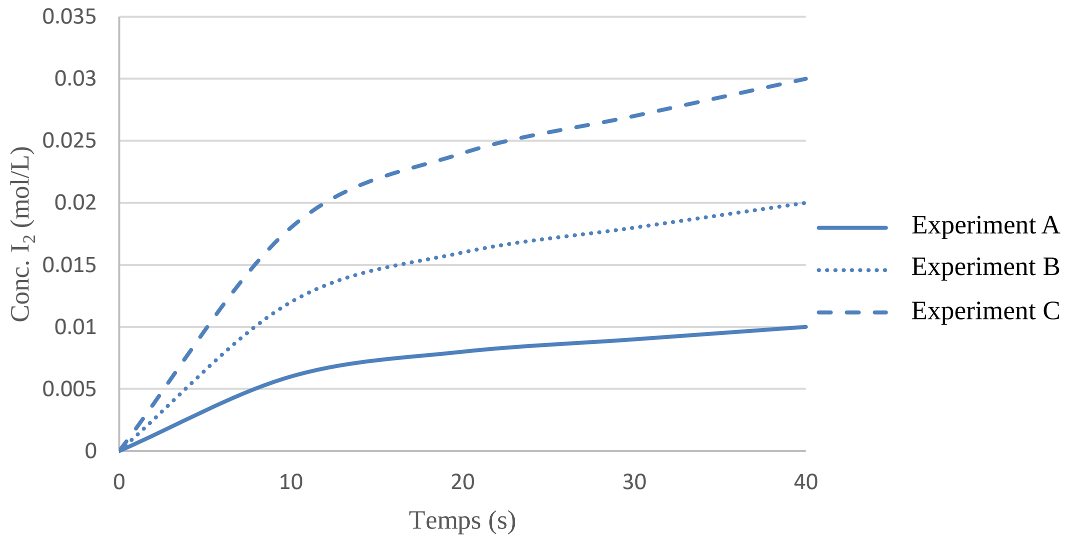
The oxidation reaction of iodide ions by peroxydisulfate ions (persulfates) in aqueous solution:

$$2\ I^-\ (aq) + S_2O_8^{2-}\ (aq) \rightarrow I_2(aq) + 2\ SO_4^{2-}\ (aq)$$

3 experiments are carried out, A, B and C, during which the change of the iodine concentration (I_2) is determined experimentally as the reaction progresses. For each experiment, the initial concentration of iodide ions ($[I^-]_0$) is modified. The following table specifies the conditions for each experiment:

Experiment	$[I^-]_0$ (mol·L^{-1})	$[S_2O_8^{2-}]_0$ (mol·L^{-1})	Temperature (K)
A	2,00 10^{-2}	1,00	293
B	4,00 10^{-2}	1,00	293
C	6,00 10^{-2}	1,00	293

The results of the experiments have been graphed below.



Based **ONLY** on the experimental data provided:

a) The slowest reaction is :	A	B	C
b) The fastest reaction is :	A	B	C
c) The speed of the reaction is influenced by the $[I^-]_0$	Yes	No	Impossible to determine
d) The speed of the reaction is influenced by temperature.	Yes	No	Impossible to determine
e) The speed of the reaction is influenced by $[S_2O_8^{2-}]_0$	Yes	No	Impossible to determine

Circle the correct response.

CHEMSITRY OLYMPIAD 2020

DRAFT SHEET