CHIMIESOLYMPIAD
LËTZEBUERG 2019

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 endeavors.

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 Wednesday, March 20, 2019 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 Wednesday, April 24th.

This last event will select, among them, the four students who will participate in the 51th IChO in Paris, from July 21 to 30, 2019.

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)

TABLEAU PÉRIODIQUE DES ÉLÉMENTS

masse atomique relative A_r — élément — nombre atomique

1 I a																	18 VIII a
1,01 **H** 1	2 II a											13 III a	14 IV a	15 V a	16 VI a	17 VII a	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	3 III b	4 IVb	5 V b	6 VI b	7 VII b	8 VIII b	9 VIII b	10 VIII b	11 I b	12 II b	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

∗ Eléments n'ayant pas de nucléide (isotope) de durée suffisamment longue et n'ayant donc pas une composition terrestre caractéristique.

Constants

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

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

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

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

$N_A = 6{,}02 \times 10^{23}$ 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 2019

QUALIFICATION ROUND

Name :

First name :

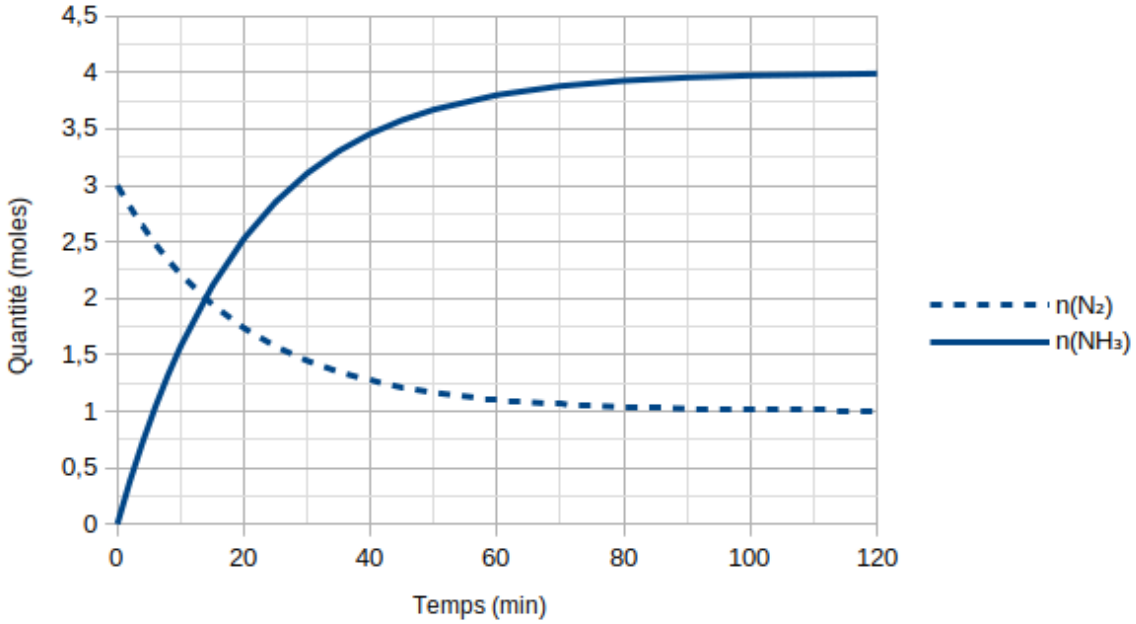
School :

6 pts	**QUESTION I – Kinetics of the synthesis of ammonia**

When studying the kinetics of this reaction the following equation shows this equilibrium:

$$3\ H_2 + N_2 \rightleftharpoons 2\ NH_3$$

This reaction is carried out by reacting 9.0 moles of H_2 (g) with 3.0 moles of N_2 (g) in a 1.5 L chamber. The amount of material at equilibrium is determined by titration of the number of moles of NH_3 produced and the number of moles of N_2 after several reaction times. The results are shown in the following graph.



2pts

1. After how long was equilibrium reached?

   a) 17 s b) 6000 s c) 1000 s d) 100 s

4pts

2. Estimate the equilibrium constant.

a) $7{,}50\times10^{-1}$ b) $9{,}26\times10^{-3}$ c) 1,33 d) $4{,}17\times10^{-2}$ e) $5{,}93\times10^{-1}$

Circle the correct response(s).

5 pts | **QUESTION II – Blood minerals**

In the Eastern part of the Democratic Republic of Congo, the minerals market is raging against the backdrop of civil war, looting and illegal trade. After the United States, the European Union plans to ban the import of these "blood ores" by setting up a certification and traceability system which, will not harm or impact on the miners.

The main metals identified are tungsten, tin, coltan and gold. Coltan is a compound of columbium (currently referred to as niobium) and tantalum, which is particularly appreciated for its resistance to heat.

a) Write the correct chemical symbol by each of the metals listed.
b) Identify each metal with its main use.

10x 0,5pt

	Metal	**Chemical symbol**
A	Niobium	
B	Tantalum	
C	Tungsten	
D	Gold	
E	Tin	

Use	**Metal associated with this use**
Acts as a container for canned goods	
An element in the family Vb, next to Vandium, used in the making of the alloy of steel in the Millau bridge.	
Found in the US bank reserves.	
Found as a filament in lightbulbs. Recently removed from trade.	
Essential in the manufacture of capacitors in mobile phones.	

8 pts | **QUESTION III – Explosion of nitroglycerine**

The detonation of nitroglycerine occurs according to the following equation:

$$\_\_\ C_3H_5N_3O_9(l) \rightarrow \_\_\ CO_2(g) + \_\_\ H_2O(g) + \_\_\ N_2(g) + \_\_\ O_2(g)$$

5pts

1. Balance the equation using the above spaces.

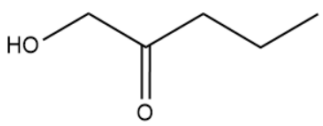
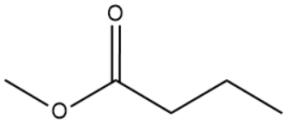
3pts

2. How many moles of gas are produced from the decomposition of 227.11g of nitroglycerine ?

a) 1 b) $\frac{29}{4}$ c) $\frac{29}{2}$ d) 29 e) 58

Circle the correct response(s).

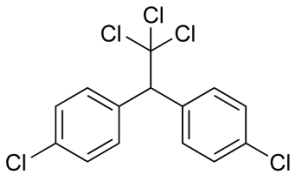
3 pts	**QUESTION IV – Acid- Base reactions**
3pts	What is the concentration of hydroxide ions (OH^-) in a 1 Molar solution of a monoprotic acid ? a) $1,0x10^{-1}$ b) $1,0x10^{-14}$ c) $1,0x10^{-7}$ d) 1,0 *Circle the correct response(s).*

10 pts	**QUESTION V – Isomers and organic acids**
4pts	Carboxylic acids are found commonly within our environment, for example: methanoic (formic) acid normally secreted by ants, ethanoic (acetic) acid constituting vinegar, butanoic (butyric) acid found in rancid butter. The next acid in the family has 5 carbon atoms and has the molecular formula : $C_5H_{10}O_2$. 1. How many possible isomers can be made from this carboxylic acid $C_5H_{10}O_2$? a) 1 b) 2 c) 3 d) 4 e) 5 f) 6 *Circle the correct response.*
4pts	2. Amongst the molecular and structural formulas below, which one corresponds to one of the isomers from the previous question? a) CH_3-CH_2-CH=CH-COOH b)  c) CH_3-$C(CH_3)_2$-COOH d)  *Circle the correct response*
2pts	3. From a reaction between a carboxylic acid and an alcohol, what is the type of compound produced when in the presence of an acid catalyst ? a) An ester b) A ketone c) A di-alcohol d) An aldehyde e) A di-acid *Circle the correct response*

7 pts	**QUESTION VI – Equilibrium changes**
7x 1pt	Using the following equilibrium reaction, indicate what change would happen to the direction of the equilibrium in the following circumstances. $2\ SO_3\ (g) \rightleftharpoons 2\ SO_2\ (g) + O_2(g) \quad (\Delta H > O)$ For your notations use →, ← or X if you think there would be no change to the position of the equilibrium.

	→	←	X
a) Addition of sulfur dioxide			
b) Increase of the temperature :			
c) Decrease in volume, whilst temperature remains constant.			
d) Decrease the concentration of oxygen:			
e) Decrease the total pressure:			
f) Addition of helium :			
g) Add an inhibitive catalyst :			

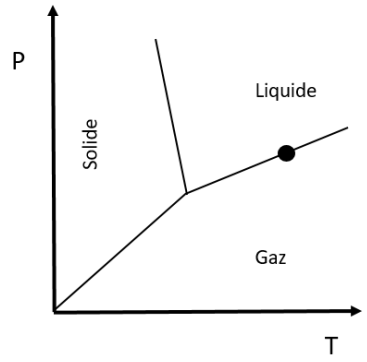
Place an x in the correct box

3 pts	**QUESTION VII – DDT**
3pts	DDT is an insecticide that is no longer used due to its toxicity. Here is the structural formula of a molecule DDT, give the molecular formula in the space below. 

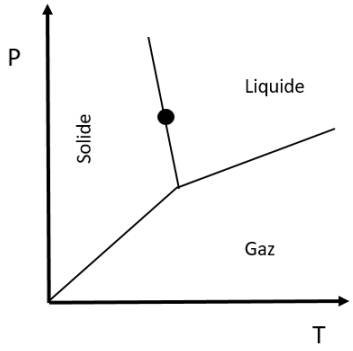
6 pts	**QUESTION VIII –Taking Gas to Mars**
6pts	During an expedition to the planet Mars, astronauts take with them a one litre bottle, filled with helium gas. This bottle was filled in California, at a temperature of 27 ° C, and at a pressure of 24.67 atm. On the surface of Mars, where the atmospheric pressure is 5.7 mmHg and the temperature is -13 °C during the day, the total amount of helium contained in the bottle is used to inflate a meteorological balloon. Determine the temperature on the surface of Mars during the night, knowing that the volume of this balloon during the night is equal to 2.33 m^3. a) -40,5°C b) -140,5°C c) -212,5°C d) -60,5°C *Circle the correct response*

6 pts	QUESTION IX – Phase Diagrams
3x 2pts	The phase diagrams of a pure substance in different states are given to you in the diagrams below For the following descriptions, indicate which letter phase diagram corresponds to the states below. The substance is boiling. ☐ The substance is in sublimation. ☐ The substance is in a state that can only be found at a given temperature and pressure. ☐

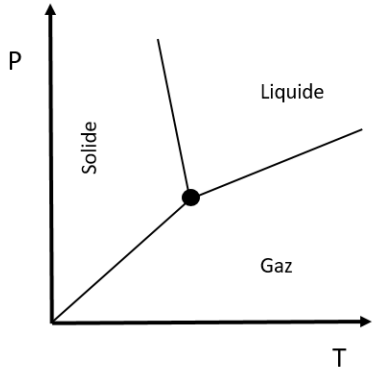
A



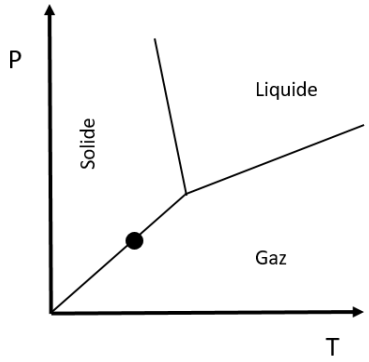
B



C



D



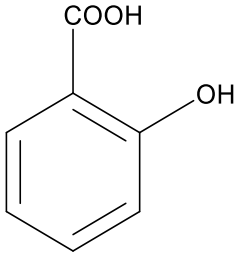
5 pts	QUESTION X – Acids and bases
5x1pt	Indicate the acid base nature of an aqueous solution of the following compounds: *Place an x in the correct box*

	Acidic	Basic	Neutral
a) Potassium bromide			
b) Ammonium perchlorate			
c) Aluminium chloride.			
d) Sodium carbonate			
e) Lithium sulphide			

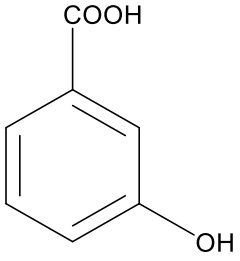
6 pts	QUESTION XI – Magnesium
6x 1pt	Starting from magnesium metal, different magnesium compounds can be obtained. In the following reactions to obtain these compounds, note in the box above the arrow the reagents and conditions necessary. For example : addition of heat, $HNO_3(aq)$…).

Mg (s)	→	MgO (s)
MgO (s)	→	$MgSO_4$ (aq)
$MgSO_4$ (aq)	→	$Mg(OH)_2$ (aq)
$Mg(OH)_2$ (aq)	→	$MgCl_2$ (aq)
$MgCl_2$ (aq)	→	$MgCO_3$ (s)
$MgCO_3$ (s)	→	MgO (s)

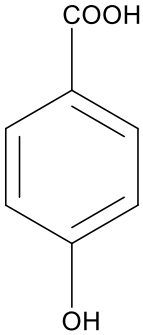
5 pts	QUESTION XII – Hydrogen bridges
5pts	The energy of hydrogen bonds is are a few tens of kJ mol^{-1}, this is about ten X less strong than that of a single covalent bond. It is however greater than van der Waals (London dispersion) forces. Hydrogen bonds can be established with other neighboring molecules such as water and between groups within the same molecule. There are three possible isomers for hydroxybenzoic acid:



A : 2-hydroxybenzoic acid



B : 3-hydroxybenzoic acid



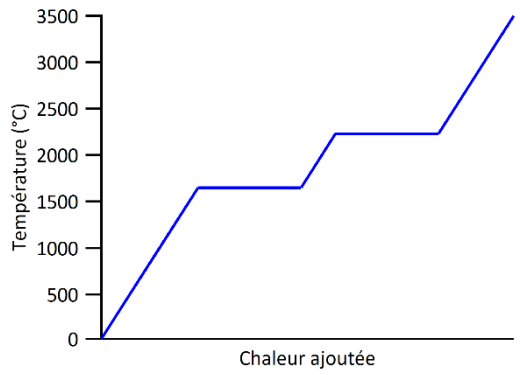
C : 4-hydroxybenzoic acid

Taking into account the possible hydrogen bonds (intra and intermolecular), place these molecules, A, B and C in ascending order of melting point.

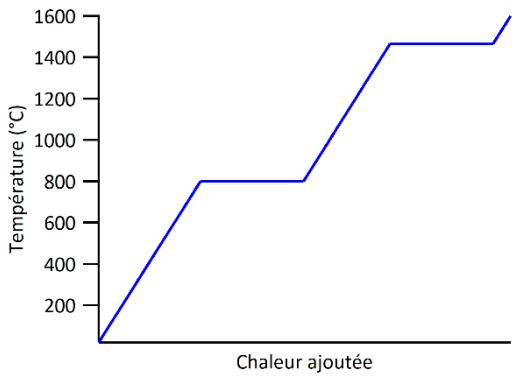
_____ < _____ <_____

6 pts	**QUESTION XIII – Changes of state and their heating curves**
4x 1,5pts	Associate each of the substances HF, H_2, SiO_2 et NaCl with the heating curves below :

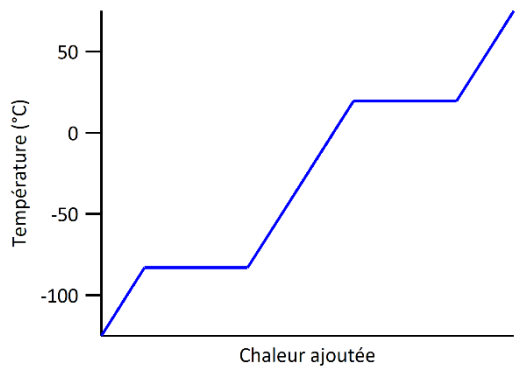
A



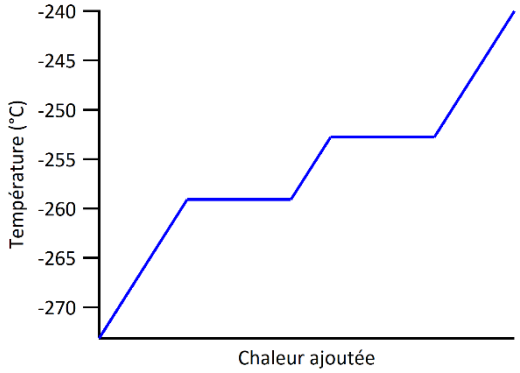
B



C



D



A : **B :** **C :** **D :**

6 pts	**QUESTION XIV – Thermochemistry**
6pts	Calculate the enthalpy change at 298K for the following reaction: $CO(g) + 3\ H_2(g) \rightarrow CH_4(g) + H_2O(l)$ Enthalpy data : $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)\ \Delta H^\circ = -882.3$ kJ $\Delta H°f\ (H_2O, l) = -286,0$ kJ mol^{-1} $\Delta H°f\ (CO_2, g) = -393,7$ kJ mol^{-1} $\Delta H°f\ (CO, g) = -110,6$ kJ mol^{-1} a) -92,0 kJ b) -258,8 kJ c) 83,4 kJ d) -83,4 kJ *Circle the correct response.*

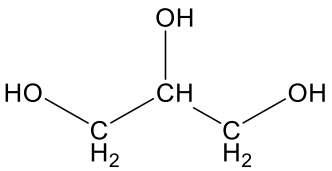
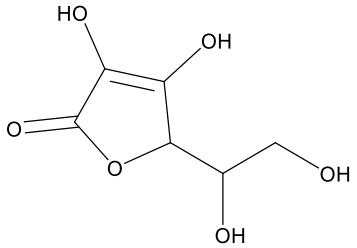
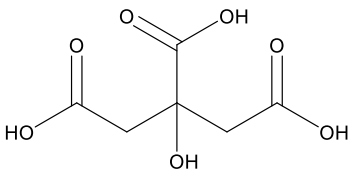
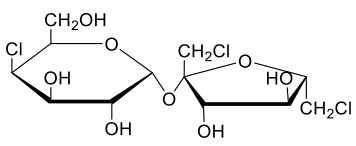
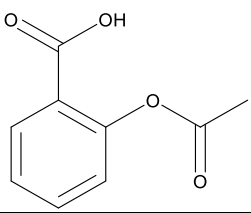
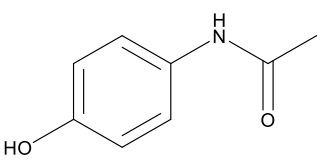
6 pts	**QUESTION XV – Bond angles**
2x 3pts	Determine the bond angles of the following molecules (FCN et FNO): 120° A little less than de 120° 180° A little less than 180° 90° A little less than 90° *Place an x in the correct box.*

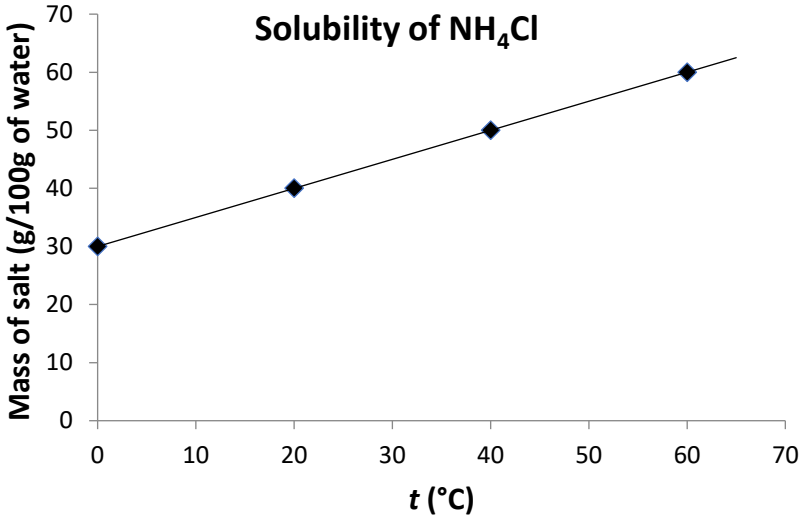
FCN	FNO

6 pts	**QUESTION XVI – Every day Organic molecules**
6x 1pt	Organic molecules are ubiquitous in our daily lives: health, clothing, housing, energy, transportation, food etc. Some of them have generic or common names. From the information below and the structural formulas shown, identify each molecule.

1. Citric acid, present in lemons is used especially in acidic sweets; its molecules contain 3 acid functional groups.	
2. Paracetamol is often used to treat fevers and headaches; its molecules contain a benzene ring and an amide functional group.	
3. Glycerol (or glycerin) is used in many pharmaceutical compounds such as a moisturizer, its molecules contain 3 alcohol functional groups	
4. Aspirin is the active ingredient of many drugs with analgesic properties; its molecules contain both a carboxylic acid and an ester functional group.	
5.Vitamin C or ascorbic acid is a vitamin with antioxidant effects; its molecules contain 4 alcohol functional groups and a 5-membered ring.	
6. Sucralose is an artificial sweetener with a sweetening power 5 to 600 times more potent than sucrose; it is also heat stable and can easily be used in the kitchen; Its molecules contain 2 cyclic ring structures and 3 chlorine atoms.	

Formulae :

A 	**B** 	**C** 
D 	**E** 	**F** 

6 pts	QUESTION XVII – The solubility of ammonium chloride
4pts	Ammonium chloride is a by-product obtained in the manufacture of sodium carbonate by the Solvay process. It is a salt whose solubility varies with temperature as shown in the graph below. Using the graph below deduce what mass of ammonium chloride can be added before the solution is saturated at 60 ° C? if an aqueous solution of ammonium chloride already contains 50 g of salt in 1000 g of pure water.  a) 0 g b) 50 g c) 250 g d) 400 g e) 500 g f) 550 g *Circle the correct response.*
2pts	The dissolving of NH_4Cl in water is which type of reaction? Endothermic | Exothermic *Circle the correct response.*

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DRAFT SHEET