

15<sup>TH</sup> INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



**Discovery, Innovation and Environment**

**Laboratory Experiment**

**– Exam Sheet –**

December 8, 2018

**Do NOT turn to next page  
before a whistle is blown.**

**Otherwise, you will receive a penalty.**

**1. You have 10 minutes to read “EXAMINATION RULES”, “EXAM INSTRUCTIONS”, and “CALCULATOR INSTRUCTIONS” on pages 1 - 3.**

**2. Do NOT start answering the questions before the “START” whistle! Otherwise, you will receive a penalty.**

**EXAMINATION RULES**

1. You are NOT allowed to bring any personal items into the examination room, except for



personal medicine or approved personal medical equipment.

2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start answering the questions before the “**START**” whistle.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigator.
6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.
7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
8. At the end of the examination time you will hear the “**STOP**” whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.



---

### **EXAM INSTRUCTIONS**

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated table.
3. Check the stationery items (pen, calculator, ruler, and scrap paper) provided by the organizers.
4. Do NOT start your experiments before the “**START**” signal.
5. You are NOT allowed to leave the examination room during the experiment, except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need assistance, raise your hand and wait for a supervisor to come.
7. You can ONLY ask questions and discuss the experiments with your own team members. You must STAY at your table until the end of the time allocated for the experiments, even if you have finished the experiments or do not wish to continue.
8. At the end of the experiment time you will hear the “**STOP**” signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, ruler, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

### **EXPERIMENT INSTRUCTIONS**

1. After the “**START**” signal, you will have 15 minutes to read the experiments. In this time, it is NOT allowed to conduct the experiment yet, or answer the questions.
2. After the first 15 minutes, another whistleblow will indicate that you can start the experiment and start answering question. From this moment you have three hours to



complete the test.

3. Use only the pen and pencil provided by the organizers.
4. The total number of experiments is 3. Check if you have a complete set of the exam sheets (20 pages, page 4 – page 20) and answer sheets (28 pages - including the front page). Raise your hand, if you find any sheets missing.
5. Check that your name, code and country are filled in on your answer sheets and sign every page of the answer sheets. Raise your hand, if you find any sheets missing.
6. Read the experimental procedures and questions carefully and write your answers in the corresponding boxes of the answer sheets.
7. When units are provided in the answer sheets, you have to write the answers correctly for the units.
8. Always show your calculations if room for this is provided. If you do not show your calculations, no points are awarded for the question.
9. You should write your final answers down in the appropriate number of digits.
10. You **MUST** wear a **Lab Coat** and **Safety Glasses** during the experiments.

### INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press  $\boxed{\text{ON/C}}$ .
2. Turning off: Press  $\boxed{2\text{ndF}}$   $\boxed{\text{ON/C}}$ .
3. Clearing data: Press  $\boxed{\text{ON/C}}$ .
4. Addition, subtraction, multiplication, and division

Example 1)  $45 + \frac{285}{3}$

$$\boxed{\text{ON/C}} \ 45 \ \boxed{+} \ 285 \ \boxed{\div} \ 3 \ \boxed{=}$$

**140.**

Example 2)  $\frac{18+6}{15-8}$



18  6    15  8   **3.428571429**

*Example 3)*  $42 \times (-5) + 120$

42  5   120  **-90.**

42    5   120  **-90.**

### 5. Exponential

*Example 1)*  $8.6^{-2}$

8.6  2   **0.013520822**

*Example 2)*  $6.1 \times 10^{23}$

6.1  10  23  **6.1 x 10<sup>23</sup>**

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press . If the cursor is located at the right end of a number/function, the  key will function as a back space key.

**Do NOT turn to next page  
Before the“START”whistle is blown.  
Otherwise, you will receive a penalty.**

**CHEMISTRY**

**Experiment II: Determination of acid content in a fruit acid solution [13.3 points]**

**ANSWER KEYS**

**Standardization of the NaOH**

Question (Points)	Record the volume of NaOH (mL) solution used in the standardization																				
<b>II-1a</b> [3.5 points]	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;"></th> <th style="width: 20%;">Titration #1</th> <th style="width: 20%;">Titration #2</th> <th style="width: 20%;">Titration ....</th> <th style="width: 25%;">Titration .....</th> </tr> </thead> <tbody> <tr> <td>Initial Vol.</td> <td>.....</td> <td>.....</td> <td>.....</td> <td>.....</td> </tr> <tr> <td>End Vol.</td> <td>.....</td> <td>.....</td> <td>.....</td> <td>.....</td> </tr> <tr> <td>Vol. Used</td> <td>.....</td> <td>.....</td> <td>.....</td> <td>.....</td> </tr> </tbody> </table> <p>[1.0 for proper and consistent recording and 0.5 point for at least two titrations]</p> <p>Average NaOH volume used .....<span style="background-color: yellow;">xxxxx</span>.....mL [0.5]</p> <p>Precision = [max 0.5] <math>\pm 0.1</math>, [award 0.5], <math>\pm 0.2</math>, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations</p> <p>Accuracy = [max 1.0] <math>\pm 0.3</math> [award 1.0], <math>\pm 0.5</math> [award 0.5], <math>\pm 1.0</math> [award 0.25]</p>		Titration #1	Titration #2	Titration ....	Titration .....	Initial Vol.	.....	.....	.....	.....	End Vol.	.....	.....	.....	.....	Vol. Used	.....	.....	.....	.....
	Titration #1	Titration #2	Titration ....	Titration .....																	
Initial Vol.	.....	.....	.....	.....																	
End Vol.	.....	.....	.....	.....																	
Vol. Used	.....	.....	.....	.....																	

Question (Points)	Write down a balanced chemical equation for the titration reaction of oxalic acid (H <sub>2</sub> X) with NaOH
<b>II-1b</b> [0.25 points]	$2\text{NaOH} + \text{H}_2\text{X} \dots \text{Na}_2\text{X} + 2\text{H}_2\text{O}$ <p>If not balanced subtract 0.1 points</p>
Question (Points)	Calculate the concentration of the NaOH solution
<b>II-1c</b> [0.5 points]	<p>Mol of H<sub>2</sub>X = 0.100 mol/L x 10 mL/1000 mL = xxxx mol</p> <p>Mol ratio of NaOH to H<sub>2</sub>X = 2:1 [0.25]</p> <p>Mol of NaOH = xxxx mol x 2</p> <p>Concentration of NaOH = xxx/ Titre value = yyy mol/L [0.25]</p> <p>Accept alternative suitable calculations</p>

**Titration of fruit acid solution**

Question (Points)	Record the volume of NaOH (mL) solution used			
<b>II-2</b>  [3.5 points]	Titration #1	Titration #2	Titration .....	Titration .....
	Initial Vol. ....	.....	.....	.....
	End Vol. ....	.....	.....	.....
	Vol. Use ....	.....	.....	.....
	<p>[1.0 for proper and consistent recording and 0.5 point for at least two titrations]</p> <p>Average NaOH volume used ..... <b>25.65 ml</b>..... mL</p> <p>[0.5]</p> <p>Precision = [max 0.5] ±0.1, [award 0.5], ±0.2, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations</p> <p>Accuracy = [max 1.0] ± 0.3 [award 1.0], ±0.5 [award 0.5], ±1.0 [award 0.25]</p>			

Question (Points)	Write down the balanced equation for the titration reaction
<b>II-3</b>  [0.25 points]	$\text{HA}_{(aq)} + \text{NaOH}_{(aq)} \rightarrow \text{NaA}_{(aq)} + \text{H}_2\text{O}_{(l)}$ <p>Do not penalize for the state symbols</p>



Question (Points)	Determine the number of moles of NaOH used in the titration
<b>II-4</b>  [0.5 points]	<p>Moles = Con x vol</p> <p>= 0.1 mol/L x 25.65 x 10<sup>-3</sup> L [0.25]</p> <p>= 2.565 x 10<sup>-3</sup> mol [0.25]</p>

Question (Points)	Determine the mass (g) of acid in the fruit acid solution titrated with NaOH solution
<b>II-5</b>  [1.0 points]	<p>Mole ratio of NaOH : HA is 1:1 [0.25]</p> <p>HA moles = 2.565 x 10<sup>-3</sup> mol [0.25]</p> <p>MW of HA = 60.0 g/mol</p> <p>Mass of HA = 2.565x10<sup>-3</sup> x 60.0 g/mol [0.25]</p> <p>= 1.539 x 10<sup>-1</sup> g or 0.1539 g [0.25]</p>

Question (Points)	Assuming the density of fruit acid solution is 1.005g/mL, determine the mass (g) of 4 mL solution.
<b>II-6</b> [0.5 points]	<p>Mass = density x volume</p> <p>1.005g/mL x 4.0 mL [0.25]</p> <p>4.02 g [0.25]</p>

Question (Points)	Determine the % mass of the acid in fruit acid solution.
<b>II-7</b> [0.5 points]	<p>= 0.1539 g/4.02 g x 100% [0.25]</p> <p>= 3.83 % [0.25]</p>

Question (Points)	Calculate the volume of the fruit acid solution that the student used?
<b>II-8</b> [1.0 points]	<p>Mole of NaOH = 0.54 mol/L x 25 x 10<sup>-3</sup>L</p> <p>= 0.0135 mol [0.25]</p> <p>Moles ratio is 1:1, therefore HA mol is 0.0135 mol. [0.25]</p> <p>Concentration of fruit acid solution = moles/volume = 2.565 x 1.35x10<sup>-</sup></p>

	$\frac{3 \text{ mol}}{25.65 \times 4 \times 10^{-3} \text{ L}}$ $= 0.641 \text{ mol/L}$ <p>Volume of fruit acid solution required = moles/conc</p> $= 0.0135 \text{ mol} / 0.641 \text{ mol/L}$ $= 0.021 \text{ L}$ $= 21 \text{ mL} \quad [0.5]$ <p><i>OR Volume of fruit acid solution = 25 mL x 0.54 mol/L / 0.641 = 21.09 mL [0.5]</i></p>
--	--

Question (Points)	Another student has measured the pH of the fruit acid solution to be 2.75. Use this value and your data to determine the pK <sub>a</sub> of the fruit acid solution.
II-9 [0.5 points]	$\text{pKa} = \text{Sq of pH}$ $= \text{????????}$

Question (Points)	Calculate the $K_b$ of the conjugate base of the fruit acid solution
<b>II-10a</b> [0.5 points]	$pK_a + pK_b = 14$ $14 - pK_a = y$ $K_b = 10^{-y}$

Question (Points)	Calculate the pH at end point. Use the $K_b$ from the previous question
<b>II-10b</b> [0.5 points]	$K_b = \frac{[HA][OH]}{[A]}$ $K_b = \frac{X^2}{x-z}$ $z = \text{mol HA} / 4 \times 10^{-1}$

Question (Points)	If phenolphthalein was unavailable, which of the following indicators would be most suitable for this titration.																					
<b>II-11</b> [0.3 points]	Tick the correct box <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Indicator</th> <th>pKa</th> <th></th> </tr> </thead> <tbody> <tr> <td>Methyl violet</td> <td>0.8</td> <td></td> </tr> <tr> <td>Thymol blue</td> <td>1.6</td> <td></td> </tr> <tr> <td>Methyl yellow</td> <td>3.3</td> <td></td> </tr> <tr> <td>Bromocresol green</td> <td>4.7</td> <td></td> </tr> <tr> <td>Thymol Blue</td> <td>8.9</td> <td style="text-align: center;">✓</td> </tr> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Indicator	pKa		Methyl violet	0.8		Thymol blue	1.6		Methyl yellow	3.3		Bromocresol green	4.7		Thymol Blue	8.9	✓			
Indicator	pKa																					
Methyl violet	0.8																					
Thymol blue	1.6																					
Methyl yellow	3.3																					
Bromocresol green	4.7																					
Thymol Blue	8.9	✓																				



15<sup>th</sup> International Junior Science  
Olympiad  
University of Botswana  
December 8, 2018

**Laboratory Experiment**

Time : 3 hr

Points : 30

**Page 12**