15TH 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 the “EXAMINATION RULES”, “EXPERIMENT INSTRUCTIONS” and “CALCULATOR INSTRUCTIONS” on pages 1 - 4.

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

EXAMINATON 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 table.
3. Check the stationery items (pen, pencil, 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 questions. 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 (19 pages, page 4 – page 19) and answer sheets (23 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.

CALCULATOR INSTRUCTIONS

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

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

   [ON/C] *45* [+] *285* [÷] *3* [=] **140.**

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

   [ON/C] [(] *18* [+] *6* [)] [÷] [(] *15* [−] *8* [)] [=] **3.428571429**

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

   [ON/C] *42* [×] *5* [+/−] [+] *120* [=] **-90.**

   [ON/C] *42* [×] [(] [−] *5* [)] [+] *120* [=] **-90.**

5. Exponential

   Example 1) 8.6^{-2}

   [ON/C] *8.6* [y^x] *2* [+/−] [=] **0.013520822**

   Example 2) 6.1×10^{23}

   [ON/C] *6.1* [×] *10* [y^x] *23* [=] **6.1×10^{23}**

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press [DEL]. If the cursor is located at the right end of a number/function, the [DEL] 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.

INTRODUCTION

The population of the earth has grown rapidly over the past decades. To address the demand of a sustainable source of food, plant-based nutrition is gaining importance. To further facilitate this development, modern food engineering focuses on enhancing the properties of plant products, besides nutritional value alone. Extracted plant oils can be used as emulsifiers or a more sustainable energy source; isolated plant pigments offer natural food coloring options or a basis for diverse technological products such as solar panels; plant organic acids can be used as natural preservatives to extend the shelf life of food products or influence the digestion of carbohydrates. Such developments aim to diminish the dependence on fossil resources and rare earths.

This experiment lets you explore the properties of several plant extracts directly.

BIOLOGY LABORATORY PRACTICAL

Total points [13.4 points]

Experiment I: Using thin layer chromatography technique to identify plant compounds

Thin-layer chromatography (TLC) is a technique used to identify compounds contained within biological extracts (e.g. plant extracts from steam distillation). As in other chromatographic methods, TLC is based on the principle of differential separation of compounds within a mixture. However, unlike other chromatographic methods, TLC is a simple, relatively cheap, highly sensitive and has a short development time.

The TLC system consists of different components such as TLC plates, chamber and mobile phase. TLC plates are usually ready-made and are coated with a thin layer of a stationary phase. The stationary phase of the plates is applied uniformly (uniform thickness throughout the plate). The TLC plates are developed in a TLC chamber, which contains the mobile phase. The mobile phase is made of a solvent (or mixture of solvents) which is chemically inert with the sample and is of high purity. It helps to separate compounds as they move up the TLC plate. Upon completion of the vertical separation of different compounds (which will appear as spots), each compound/spot will have a retention factor (also known as retardation factor) R_f value. The R_f value is calculated using the following formula:

$$R_f = \text{(distance travelled by compound) / (distance travelled by mobile phase)}$$

Since R_f values are unique for each compound, they can be used to identify different compounds. Within plant extracts, TLC can separate and help indicate presence of different compounds such as plant pigments and secondary metabolites. These compounds occur naturally in plants and are often found as a mixture within plant extracts. However, they each have unique R_f values which can help to identify them within the mixture.

Solutions A-D (provided to you) are made of different plant extracts.

Using the TLC technique and protocol below identify compounds found in each of the solutions A-D.

Materials provided

1. One TLC plate
2. Pencil
3. 10 µL capillary tubes (four tubes, in a Petri dish)
4. Four solutions (A-D)
5. TLC chamber (jar) and lid, containing mobile phase (cyclohexane: petroleum ether: ethyl acetate: acetone: methanol in a ratio of 16:60:10:10:4)
6. Ruler
7. Latex gloves
8. Paper towel

Procedure

Notes:

- ***Only a single TLC plate is provided per team. Prepare and use your plate with utmost care, following the procedure outlined below***
- ***The black mark on the capillary tube denotes the 10 µL mark***
- ***Use only pencil when drawing or writing on a TLC plate***
- ***Wear gloves when handling TLC plates***
- ***When opening and closing the TLC chamber, avoid inhaling vapors from the chamber***

1. Place the chromatography plate on a clean surface (paper towel). Draw two straight lines across the TLC plate, 1.5 cm from one end (the bottom) and 1 cm at the other end (the top). Without putting the plate into the TLC chamber, check that it will fit in the chamber.
2. On the line at the bottom, make 4 spots 1 cm apart from each other (the first and last spots should be 0.75 cm away from the edge of the TLC plate). Label each spot A-D.
3. Use a capillary tube to load about 5 µl of sample A on the pencil spot marked A. The sample should be placed drop by drop. A**llow each drop to dry before loading another.** Make sure the sample does not spread to make a circle over a diameter of 0.75 cm. Repeat for samples B-D. See Figure 1 for example of TLC plate. **Note, if the capillary tube breaks, immediately request a replacement one.**

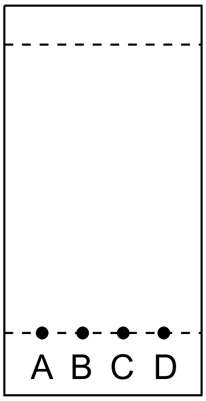

Figure 1: Example of a TLC plate with sample spots

4. Once done, carefully place the TLC plate in the jar containing the mobile phase (spotted side facing you).
5. Close the chamber **tightly** with the lid and watch the mobile phase move up your TLC plate.
6. When the mobile phase reaches the top pencil line that you marked remove the TLC plate, place it on the paper towel and allow it to dry.
7. Use your TLC plate and the information provided in Table 1 to answer the questions that follow.
8. Get the invigilator to take a photograph of your original TLC plate and to sign your answer sheet (this can be done at any time during the experiment)

Table 1: Plant pigments and their R_f values, determined using the above procedure

Plant pigment		**R_f value**
i)	Xanthophyll 2	0.15
ii)	Xanthophyll 1	0.28
iii)	Rutin	0.34
iv)	Chlorophyll b	0.42
v)	Gallic acid	0.54
vi)	Chlorophyll a	0.59
vii)	Pheophytin	0.81
viii)	Carotene	0.98

Questions

DO NOT PROVIDE YOUR FINAL ANSWERS HERE. USE THE ANSWER SHEET

I-1. **[7.15 points]** In your answer sheet, draw a sketch of all the spots observed in lanes A-D on your TLC plate, and complete the table with R_f values and proposed pigments (Roman numeral from Table 1, one per spot) Note that not all pigments in your sample are present in Table 1.
Get your invigilator to take a photograph of your original TLC plate and sign your answer sheet.

I-2. **[1.0 point, 0.25 per statement]** For the following observations about the sample in lane D, mark in your answer sheet whether the following statements are true or false.

Statement	True	False
It separated into distinct pigments, which are not present in other lanes.		
It separated into distinct pigments, which are also present in other lanes.		
It did not move with mobile phase.		
It does not contain any pigments		

I-3. **[1.0 point, 0.25 per statement]** For the following statements, mark in your answer sheet whether the following statements are true or false

The TLC chamber (bottle) is closed to…

Statement	**True**	**False**
prevent evaporation of the mobile phase.		
avoid the smell of the chemicals contained in the mobile phase.		
maintain a dust-free environment.		
decrease the pressure in the chamber.		

I-4. **[1.75 points, 0.25 per statement]** Indicate in your answer sheet, whether each of the factors below affect the R_f value of a compound

Factor	**Affects R_f**	**Does not affect R_f**
Polarity of compound		
Distance travelled by solvent (mobile phase)		
Size of TLC plate		
Type of stationary phase		
Amount of sample loaded		
Size of chamber		
Color of the sample		

I-5. **[0.25 points]** Write the letter that corresponds to the pigment that moves slowest up the TLC plate in the box on your answer sheet.

A. Chlorophyll *a*
B. Xanthophyll 1
C. Pheophytin
D. Chlorophyll *b*

I-6. **[1.0 point, 0.25 per statement]** For the following statements, mark in your answer sheet whether the statements are correct or incorrect.

A compound moves slower than others up a TLC plate in our experimental conditions because…

Statement	Correct	Incorrect
It is less polar than the other compounds		
It is a more hydrophilic compound		
It has a larger molecular weight		
It is more concentrated than the other compounds		

I-7. **[0.25 points]** Will the R_f values change if the ratio of polar and non-polar solvents in the mobile phase is changed? Write the letter that corresponds to your answer in the box on your answer sheet.

A. Yes
B. No

I-8. **[1.0 point, 0.25 per statement]** Indicate in your answer sheet, whether each of the factors could potentially limit the effectiveness of the chromatographic technique you have used.

Factor	Limits effectiveness	Does not limit effectiveness
Leaving the TLC chamber open		
The amount of mobile phase in the TLC chamber		
Geographical location where the experiment is performed		
Running multiple plates in one TLC chamber		

CHEMISTRY LABORATORY PRACTICAL

Total points [13.3 points]

Experiment II: Determination of acid content in a fruit acid solution

The purpose of this experiment is to investigate the acid concentration and properties of the fruit acid. The active ingredient in the fruit solution is a weak acid, which can be titrated with a base in an acid-base neutralization reaction. The abbreviation for the fruit acid is HA. The sodium hydroxide solution will neutralize the fruit acid, HA, which is monoprotic. HA has the molecular mass of 60g/mol. Before you determine the concentration of the fruit acid solution you need to standardize the sodium hydroxide solution using oxalic acid of a known concentration (0.100 mol/L). Note that Oxalic acid is a diprotic acid and may be represented as H_2X.

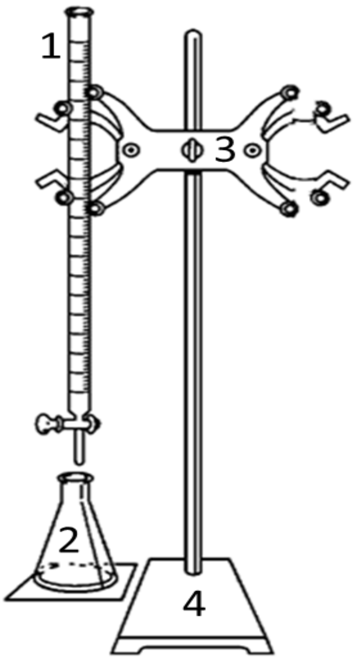

Figure II-1: A diagram showing the set-up for titration.
Key: **1**. Burette, **2**. Conical flask, **3**. Clamp **4**. Stand

Materials provided

1. 10 mL graduated pipette (x 2)
2. Glass funnel
3. Pipette filler
4. 3 x Beakers
5. White ceramic tile
6. 100 mL graduated measuring cylinder
7. Phenolphthalein indicator in a bottle, with dropper
8. Paper towel
9. Distilled water bottle

Procedure

Standardization of the NaOH

III-1. Using a 10 mL pipette place 10.0 mL of 0.100 mol/L oxalic acid solution into the 250-mL conical flask.

III-2. Add 2 to 3 drops of phenolphthalein indicator.

III-3. Titrate to the end point with the NaOH solution.

III-4. Repeat this process (Steps 1-3), until your results are coherent.

Titration of fruit acid solution

III-5. Using a graduated pipette place 4.0 mL of the fruit acid solution into the 250-mL conical flask.

III-6. Add about 50 mL of distilled water into the same 250 mL conical flask.

III-7. Add 2 to 3 drops phenolphthalein indicator.

III-8. Titrate to the end point with the standardized NaOH solution.

III-9. Repeat this process (Steps 5-8), until your results are coherent.

Questions

DO NOT PROVIDE YOUR FINAL ANSWERS HERE USE THE ANSWER SHEET

Standardization of the NaOH

II-1a. [3.5 points] In your answer sheet, record the volume of NaOH (mL) solution used in the standardization

Record the volume of NaOH (mL) solution used in the standardization

	Titration #1	Titration #2	Titration ….	Titration …..
Initial Vol.	………..	……..…..	……….	……….
End Vol.	……….	…………	….…….	………
Vol. Used	…………	………….	……….	………

Average NaOH volume used…………………………..………………mL

II-1b. [0.25 points] Write down a balanced chemical equation for the titration reaction of oxalic acid (H_2X) with NaOH

II-1c. [0.5 points] Calculate the concentration of the NaOH solution

Titration of fruit acid solution

II-2. [3.5 points] In your answer sheet, record the volume of NaOH (mL) solution used

Record the volume of NaOH (mL) solution used				
	Titration #1	Titration #2	Titration ….	Titration …..
Initial Vol.	………..	……..…..	……….	……….
End Vol.	……….	…………	…..…….	………
Vol. Used	…………	………….	……….	………
Average NaOH volume used……………………………..………………mL				

II-3. [0.25 points] Write down the balanced equation for the titration reaction between fruit acid (HA) and NaOH

II-4. [0.5 points] Determine the number of moles of NaOH used in the titration.

II-5. [1.0 point] Determine the mass (g) of acid in the fruit acid solution titrated with NaOH solution

II-6. [0.5 points] Assuming the density of fruit acid solution is 1.005 g/mL, determine the mass (g) of 4 mL solution.

II-7. [0.5 points] Determine the % mass of the acid in fruit acid solution

II-8. [1.0 point] A student used a different NaOH solution and required 25 mL of 0.54 mol/L NaOH to neutralize a sample of the same fruit acid solution. Calculate the volume of the fruit acid solution that the student used?

II-9. [0.5 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_a of the fruit acid solution.

II-10a. [0.5 points] Calculate the K_b of the conjugate base of the fruit acid solution

II-10b. [0.5 points] Calculate the pH at the end point, assuming that the final volume of the solution is 100 mL. Use the K_b from the previous question

II-11. [0.3 points] If phenolphthalein was unavailable, which of the following indicators would be most suitable for this titration.

In your answer sheet, mark the correct box with an "X"

Indicator	pKa	
Methyl violet	0.8	
Thymol blue	1.6	
Methyl yellow	3.3	
Bromocresol green	4.7	
Thymol Blue	8.9	

PHYSICS LABORATORY PRACTICAL

Total points [13.3 points]

Experiment III: Determination of the coefficient of viscosity of oil

While water can be poured from one container to another easily, honey takes a very long time to flow out of its container. The reason for these different rates of flow is that honey is more viscous and resists flow more than water does. The coefficient of viscosity is a measure of the degree of internal resistance to flow and shear. Coefficient of viscosity is an important parameter in the food industry. Flow of various components of the raw materials to the final product in an automated food industry will depend on this.

The viscosity of a fluid can be determined by measuring the velocity of a falling sphere through a column of fluid of unknown viscosity. This is accomplished by dropping a sphere through a measured distance in a column of fluid and measuring how long it takes to travel the distance.

Materials provided

1. Thermometer
2. Balls of 4 different diameters
3. Cylindrical vertical tube filled with oil
4. Stopwatch
5. Meter ruler
6. Tape to mark
7. Paper towel
8. Magnet

Theoretical aspects

Consider a spherical ball bearing of radius r and density ρ_s falling through a column of fluid of coefficient of viscosity η and density ρ_f as illustrated in Figure 1 below.

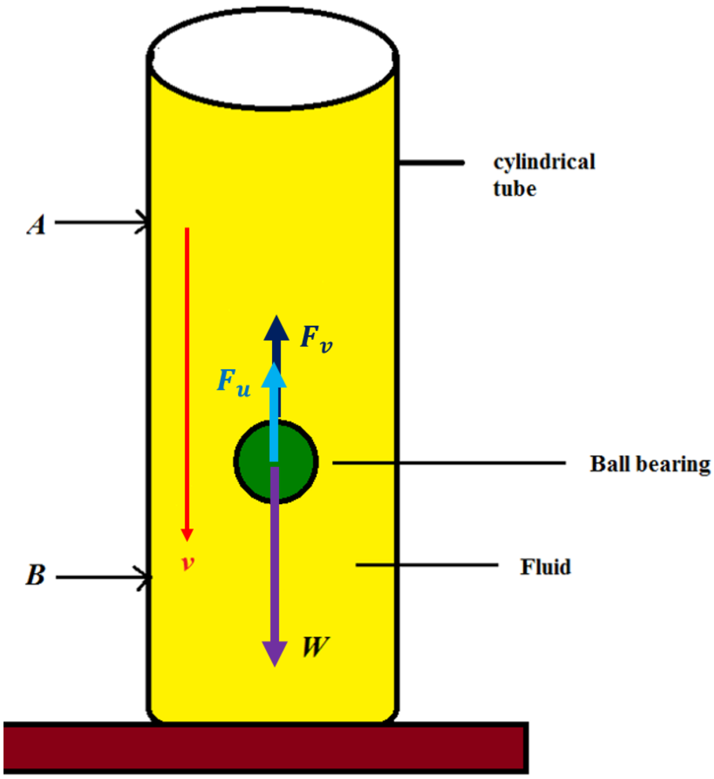

*Figure 1: Showing a spherical ball of radius r falling through a column of fluid of density ρ_f. **A** and **B** marks the distance travelled by the sphere at terminal velocity v_t.*

Initially the ball has some downward acceleration a until the ball acquires a constant velocity, called terminal velocity v_t. According to Newton's second law:

$$\text{Net Force} = ma$$

$$ma = W - (F_u + F_v) \quad (1)$$

Where:

m is the mass of the ball.
$W = mg$ is the weight of the ball.
$F_u = \frac{4}{3}\pi r^3 \rho_f g$ is the buoyant force = weight of the fluid displaced (Archimedes law)
$F_v = 6\pi \ \eta \ r \ v$ is the viscous force (of a sphere of radius r) proportional to the velocity v of the ball (Stokes's Law).

Secondly when the ball attains terminal velocity before point **A**, there is no more acceleration and hence the net force is zero. Note that ***l*** is the distance between **A** and **B** and ***t*** is the time the ball takes to fall between **A** and **B**.

Procedure **[1.3 points]**

1. Measure the temperature T_b of the oil before starting the experiment and write it in the box on the answer sheet.
2. Use the tape to mark two horizontal lines (**A** and **B**) on the cylindrical tube so that line **A** is 70 cm from the surface of the fluid. Line **B** should be approximately 50 cm below line **A**.
3. Measure the vertical distance ***l*** between lines **A** and **B** and write it in the box on the answer sheet provided.
4. Devise a method to measure the average diameter of the balls of the same size using the ruler scale as accurately as possible. Describe your method using only a sketch in the space provided.
5. Use your method to measure the average diameter of each of the four different sizes of balls and write these values in Table III-1 on the answer sheet.
6. Release one of the balls carefully into the fluid at the center of the surface (ensuring that the ball is not near the wall of the cylinder during its motion between **A** and **B**)
7. Measure the time ***t*** taken by the ball to travel the distance ***l*** between **A** and **B** and record it in the provided table.
8. Repeat steps 6 and 7 above using other balls of the same diameter to have three values of time (the magnet can be used to pull the balls along the cylinder wall out of the oil, ask for help if necessary).
9. Repeat steps 6 to 8 for the other 3 sizes of balls.
10. Measure the temperature T_a of the oil just after finishing the experiment and write it in the box on the answer sheet.

Note the following constants:

Density of the fluid	$\rho_f = 871.4\ \text{kg/m}^3$
Density of the ball	$\rho_s = 7717\ \text{kg/m}^3$
Acceleration due to gravity	$g = 9.81\ \text{m/s}^2$

Questions (results and analysis)

DO NOT PROVIDE YOUR FINAL ANSWERS HERE USE THE ANSWER SHEET

III-1. [5.0 points] Calculate the average time, d^2 and v_t for each set of ball bearings, and complete Table III-1 on the answer sheet.

Table III-1: Experimental results

Ball diameter			Diameter squared	Time taken to fall distance l				Terminal velocity
#	d (mm)	d (m)	d^2 (m^2)	t_1 (s)	t_2 (s)	t_3 (s)	Average time (s)	v_t (m/s)
1								
2								
3								
4								

III-2. [3.0 points] Plot a graph of v_t (y-axis) versus d^2 (x-axis) and draw a straight line of best fit on the grid on the answer sheet.

III-3. [1.5 points] Determine the slope of the graph. Indicate the points that are used on the graph for calculating the slope. Give your answer with appropriate units.

III-4. [1.0 points] The following formula for the terminal velocity v_t can be derived from equation (1):

$$v_t = C \cdot \frac{d^2}{\eta} \qquad (2)$$

Where $C = 3731$ kg $m^{-2}s^{-2}$.

Write down in the space provided the analytical expression for C in terms of g, ρ_s and ρ_f.

III-5. [1.5 points] Use the value of the slope to determine the coefficient of viscosity η of the oil with the appropriate units.