IJSO 2019

DOHA, QATAR

16th International Junior Science Olympiad

Practical Exam

December 9th, 2019

Please **DO NOT** turn to next page until the start signal is given.

IMPORTANT REMARKS AND SAFETY RULES

1. Always follow the instructions.
2. All competitors are expected to work safely, behave responsibly and keep the work environment clean. When carrying out discussions with your teammates, please keep your voice low so as not to disturb others.
3. Safety goggles and lab coats must be worn all the time. You may need to use the face-mask in Tasks number 1 and 3.
4. In case of chemical spills or broken glass, please raise your hand and seek assistance from Lab Assistant.
5. Eating and drinking in the lab are not allowed. If necessary, and for only medical reasons, you may ask a Lab Assistant for permission to take a snack break adjacent to the examination hall.
6. Do not leave the examination hall until you have permission to do so. Ask the Lab Assistant if you need to use the bathroom.
7. **You may only begin working on the experiments when the start signal is given.**
8. You have **4 hours** to:
   a. Complete the assigned experimental tasks,
   b. Carry out calculations,
   c. Draw graphs,
   d. Record your results on the **YELLOW** answer sheets provided.

   You must stop your work immediately after the stop command is given.
9. Make sure that your team has **three** copies of the complete booklet of the practical exam. **Only the yellow answer sheets will be marked.**
10. **Use only the pens, pencils and calculator provided. Use only the pen to write your calculations.**
11. Team code and student codes must be written on the first and the last page of the final answer sheets. **Each team member must sign on the front page of the yellow answer sheets.**
12. All results must be written in the spaces provided within the booklet. Data written elsewhere will not be graded.

13. **After the stop command is given, put the yellow answer sheets on top of the envelope on your table. Wait for the Lab Assistant to check and collect it.** The other two booklets are to be left behind: DO NOT take them with you.

The examination workstation has a built-in liquid waste disposal unit – Throw all liquid waste in the sink.

EXAMINATION RULES

1. All competitors must be present at the entrance to the examination hall **ten minutes** before the exam starts.
2. No competitors will be allowed to bring any tools except his/her personal medicine or personal medical equipment.
3. Each team has to sit at their designated table.
4. Each competitor has to check the examination booklet that is provided. Raise your hand, if you find anything missing. Start only after the bell rings.
5. The competitors are allowed neither to bother other competitors in other teams nor to disturb the examination. In case any assistance is needed, a competitor may raise his/her hand and the nearest Lab Assistant will come to help.
6. The team must stay at their table until the time allocated for the examination is over even if they have finished the examination earlier or does not want to continue working.
7. At the end of the examination time there will be a signal. You are not allowed to write anything after the signal is given. All competitors must leave the room quietly after everybody's answer sheets have been collected and you are given the signal to leave.
8. In case you need extra sample, please check with the Lab Assistant.

GENERAL INFORMATION

Constant	
Acceleration due to gravity	$g = 9.81\ m/s^2$
Universal gas constant	$R = 8.314\ \frac{J}{mol \cdot K}$
	$R = 0.08206\ L \cdot atm/mol \cdot K$
Refractive index of air	$n = 1$
Avogadro's constant	$N_A = 6.022 \times 10^{23}\ mol^{-1}$
Speed of light	$c = 2.998 \times 10^8\ m/s$
Planck's constant	$h = 6.626 \times 10^{-34}\ J \cdot s$
Specific heat capacity of water	$c_w = 4.18\ J/g \cdot °C$
Pressure	$1\ atm = 101{,}325\ Pa$
Density of water	$1\ g/mL$
Standard Deviation (s)	$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$

IUPAC Periodic Table of the Elements

1																		18
1 H hydrogen 1.008 [1.0078, 1.0082]	2											13	14	15	16	17		2 He helium 4.0026
3 Li lithium 6.94 [6.938, 6.997]	4 Be beryllium 9.0122											5 B boron 10.81 [10.806, 10.821]	6 C carbon 12.011 [12.009, 12.012]	7 N nitrogen 14.007 [14.006, 14.008]	8 O oxygen 15.999 [15.999, 16.000]	9 F fluorine 18.998	10 Ne neon 20.180
11 Na sodium 22.990	12 Mg magnesium 24.305 [24.304, 24.307]	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 26.982	14 Si silicon 28.085 [28.084, 28.086]	15 P phosphorus 30.974	16 S sulfur 32.06 [32.059, 32.076]	17 Cl chlorine 35.45 [35.446, 35.457]	18 Ar argon 39.948
19 K potassium 39.098	20 Ca calcium 40.078(4)	21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904 [79.901, 79.907]	36 Kr krypton 83.798(2)
37 Rb rubidium 85.468	38 Sr strontium 87.62	39 Y yttrium 88.906	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906	42 Mo molybdenum 95.95	43 Tc technetium	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60(3)	53 I iodine 126.90	54 Xe xenon 131.29
55 Cs caesium 132.91	56 Ba barium 137.33	57-71 lanthanoids	72 Hf hafnium 178.49(2)	73 Ta tantalum 180.95	74 W tungsten 183.84	75 Re rhenium 186.21	76 Os osmium 190.23(3)	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38 [204.38, 204.39]	82 Pb lead 207.2	83 Bi bismuth 208.98	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

Key: atomic number | Symbol | name | conventional atomic weight | standard atomic weight

57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05	71 Lu lutetium 174.97
89 Ac actinium	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

INTRODUCTION

Due to Qatar's geographic location and desert climate, which renders it without direct access to desalinated water or harvestable river systems, seawater is the most important source of water for the people of Qatar, accounting for about half of the water used.

With water sustainability being at the forefront, Qatar today primarily relies on conventional thermal desalination technologies producing huge quantities of desalinated water annually.

Qatar's three main desalination plants are:

Ras Abu Fontas B-1
Ras Laffan-A
Ras Laffan-B

Water quality is clearly of importance for humans as well as animals. One factor that influences water quality is the salt content. Some investigations show that saline water can result in a decreased milk production from camels. On the other hand, other studies show that salt content in water seems to have no effect.

Can our IJSO scientists use their knowledge of physics, chemistry and biology to distinguish between seawater and desalinated water?

Initially, you will be supplied with four different water samples.
Because you are given different samples to choose from, you **CANNOT** use taste as a method to tell the difference between seawater and desalinated water. You may end up trying to taste a sample that may be harmful !

So, let us use simple (and safe!) methods of physics, chemistry and biology to help you in your tasks.

Task 1:

Identification of Contaminated Water Samples Using Biological Methods

Suppose that you are at a desalination plant laboratory and a desalinated water sample has been accidently mixed with other samples. One of these samples is seawater. The other two samples contain water contaminated with biological materials: albumin (protein) and starch.

Principle:

i. **Proteins (= polypeptides):** are composed of amino acids. The amino (NH_2) group on one amino acid is linked to the carboxylic (COOH) group on an adjacent amino acid by a peptide bond. The copper ions in Biuret reagent complexes with at least two peptide bonds producing a change in the colour of the solution.

ii. **Carbohydrates:** have different forms like monosaccharides, disaccharides and polysaccharides (e.g. glycogen, starch and cellulose). Starch interacts with iodine in Lugol's solution producing a colour change.

iii. **Osmosis:** is the diffusion of water molecules across a selectively permeable membrane. Water moves freely across the plasma membrane of the cell. Saline solutions are hypertonic. Therefore, mixing living cells with seawater forces water to move out of the cells.

Tools and Materials:

Unknown Samples	You will be supplied with *four* samples for this task labelled as: **BIOL-A, BIOL-B, BIOL-C, BIOL-D**.
Glassware and Plastic ware	Ten test tubes, two test tube racks, three test tube holders, five 3 mL disposable plastic pipettes, one 10 mL graduated cylinder, one 10 mL pipette and one pipette filler, coloured labels.
Chemicals and Reagents	Lugol's reagent, Biuret solution.

Part A: Lugol's (Iodine) Test

Procedure:

1. Shake the unknown solutions gently and transfer 2 mL from each sample into a clean test tube;
2. Add three drops of Lugol's solution into each tube;
3. Record the obtained colour in the Table in the yellow answer sheet (Table 1) by putting a check mark (√) in the corresponding column.

Table 1. Data obtained from Lugol's test. All answers are to be recorded in the yellow answer sheet.

Observed colour	Sample (BIOL-A)	Sample (BIOL-B)	Sample (BIOL-C)	Sample (BIOL-D)
Yellowish brown				
Bluish black				

Part B: Biuret Test

Procedure:

1. Shake the unknown solutions gently, and transfer 4 mL from each sample into a clean test tube;
2. Add 4 mL of Biuret solution into each tube and mix;
   Record the obtained colour in the Table in the yellow answer sheet (Table 2) by putting a check mark (√) in the corresponding column.

Table 2. Data obtained from Biuret test. All answers are to be recorded in the yellow answer sheet.

Observed colour	Sample (BIOL-A)	Sample (BIOL-B)	Sample (BIOL-C)	Sample (BIOL-D)
Violet				
Blue				

At this stage, you will be able to identify and separate out the contaminated water samples. The two remaining samples are either desalinated water or seawater. If you are still unsure, repeat Part A and/or Part B using clean test tubes.

Part C:

You will now use biology-based experiments to identify which of the two samples is seawater.

Tools and Materials:

Glassware	Microscope slides, cover slips.
Equipment	Compound microscope, stopwatch.
Others	Tissue paper, disposable plastic pipettes, forceps, red onion, gloves, scalpel, face-mask, eye goggles, cutting board, waste bag.

SAFETY PRECAUTIONS:

1. Onion may irritate some students' eyes to the point of discomfort.
2. You might need to use face-mask and goggles to avoid any discomfort.
3. Take care with microscope slides and cover slips, which might break easily.

Waste Disposal:

Please throw the onion waste in the provided zipper plastic bag.

Procedure:

1. Cut approximately 1 cm^2 from a fleshy piece of onion and then carefully peel off a single layer of the epidermis (red skin);
2. Prepare two slide samples with a strip of the red layer on each slide;
3. Add 1-2 drops of one water sample on one of the slides and label the slide with the name of the sample;
4. Add 1-2 drops of the other water sample on the other slide and label the slide with the name of the sample;
5. Add a cover slip on each slide, carefully remove the excess liquid using tissue paper;
6. Wait for **at least 4 minutes**, and then examine the cells on each slide using a microscope. Start with the lowest power magnification.

Analysis and questions: All answers are to be recorded in the yellow answer sheet.

1- Observe the slides under the microscope; draw one cell per sample that you see in each slide, title each drawing with the appropriate sample name.

Provide a fully labelled biological drawing, including the magnification (for both of the slides) as well as to include the following key in either of the slides.

W	**Cell wall**
X	**Nucleus**
Y	**Central Vacuole**
Z	**Plasma membrane**

Based on your recorded observations, answer the following questions (<u>All answers are to be recorded in the yellow answer sheet</u>):

2- Identify the water samples, by putting a check mark (√) in the corresponding column in front of the appropriate sample name.

	BIOL-A	BIOL-B	BIOL-C	BIOL-D
Desalinated water				
Seawater				
Water contaminated with albumin				
Water contaminated with starch				

3- Onion cells in desalinated water may be described as …

I. Turgid
II. Flaccid
III. Plasmolyzed
IV. None of the above is correct

4- Blood cells do not have the same structure as plant cells. What do you think could happen to a blood cell in a desalinated water sample after 30 minutes?

I. Becomes plasmolysed
II. Shrinks
III. Remains the same
IV. Undergoes hemolysis

Task 2:

Further Validation of Water Samples' Salinity Using Physics Approaches

Assume that the two samples you identified from Task 1 were not labelled properly. Now you do not know which is which. Equipped with physics knowledge and tools, you should perform Task 2 to identify the two samples again (distinguish the desalinated water from the seawater).

First Method (Optics):

Refractive index is an important optical property of any optical medium, like water. Measurement of refractive index is often used to check the purity of a liquid and to estimate the concentrations of possible impurities. In your case, the "impurity" is salt. The idea is that upon addition of a salt, refractive index of water is expected to increase.

Several techniques exist to measure the changes in refractive index as the concentration of salt in water is changed. Such changes in refractive index are usually extremely small (in the second decimal place). Nevertheless, they can be measured if you do the following experiment with a great deal of care and high precision. In this part of the experiment, you will calculate the refractive indices of water samples using a relatively simple but effective technique.

Principle:

When an object (an arrow in this experiment) is placed in front of the reflecting surface of a concave mirror at a distance equal to its radius of curvature (PR), a real, equal and inverted image of the arrow will be formed at the centre of curvature of that mirror.

When you place a liquid like water on the reflecting surface of the concave mirror and repeat the same experiment mentioned above, you would find that the image is now located at a distance PR\ (see the figure below). In your experiment, the object is an arrow slit engraved on a wooden plate.

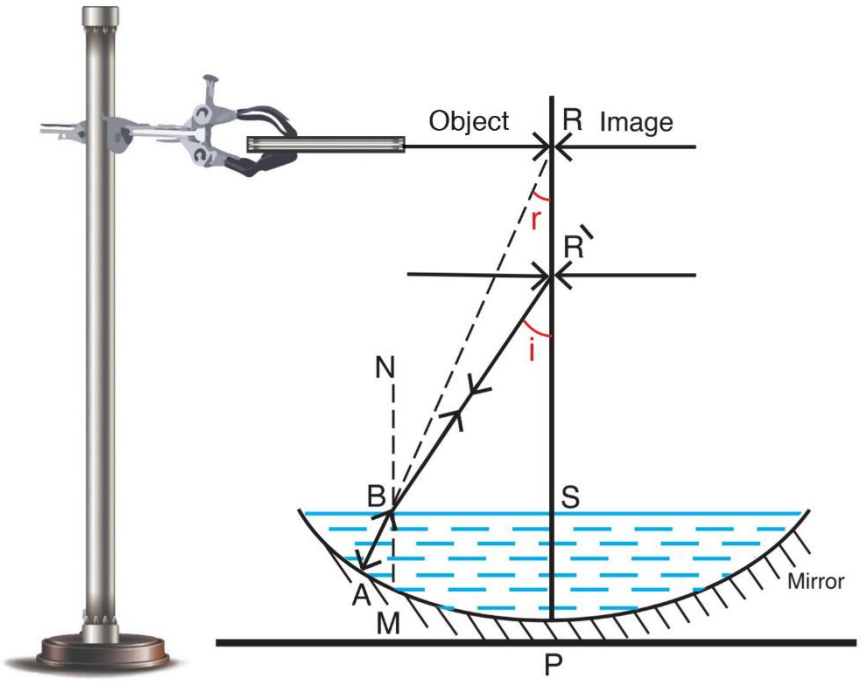


Figure 1. Schematic representation of the experiment (Not to Scale).

In your experiment, there are several approximations due to the geometry:

(1) If only little water is placed on the reflecting surface of the mirror, the distance PS can be totally neglected. This is due to the large radius of curvature of the mirror.

(2) Because your mirror has a very small aperture and a large radius of curvature, angle *i* and angle *r* are very small and distances BR and $\mathrm{BR}^{\backslash}$ can be approximated as distances SR and $\mathrm{SR}^{\backslash}$, respectively.

With water on the mirror, the incident ray from the object located at $\mathrm{R}^{\backslash}$ is refracted at the water-air boundary along the path (BA) such that it falls perpendicular to the curved reflecting surface of the mirror at point A. The reflected ray will follow bath AB in water and its trace back in air meets the principle axis at R. Meanwhile, the actual refracted ray in air travels along $\mathrm{BR}^{\backslash}$. Thus, the real, equal and inverted image is now formed at $\mathrm{R}^{\backslash}$. Therefore, the distance $\mathrm{SR}^{\backslash}$ (neglecting PS distance) would be the apparent radius of curvature of the water-filled concave mirror.

The angle of the incidence is denoted by *i* and the angle of the refraction by *r*. Thus, taking the refractive index of air to be 1.00, the refractive index of water with respect to air n_w may be expressed as:

$$n_w = \frac{\sin i}{\sin r}$$

Given the above-mentioned geometrical considerations/approximations, we can write:
$\sin i \approx \tan i$, $\sin r \approx \tan r$, and

$$n_w = \frac{\sin i}{\sin r} = \frac{\tan i}{\tan r} = \frac{\mathrm{BS}/\mathrm{SR}\backslash}{\mathrm{BS}/\mathrm{SR}} = \frac{\mathrm{SR}}{\mathrm{SR}\backslash}$$

Therefore, by placing water samples on the reflecting surface of the concave mirror and measuring SR\, you can determine the refractive index of each sample, knowing SR.

Tools:

Unknown Samples	You will be supplied with *two water* samples for this task labelled as: **PHYS-A, PHYS-B**.
Tools	Thin concave mirror, light torch (source of light), laboratory stand with rigid base, wooden sheet with an arrow sign slit, metre scale, string, disposable plastic droppers.

Procedure:

1. Place the given concave mirror on the base of the stand, keeping its reflecting surface pointing upwards. Make sure that the plane on which the mirror rests is horizontal. This makes the principal axis of the mirror vertical.
2. Adjust the position of the wooden sheet with the arrow slit (the object), so that it is horizontal and above the mirror. Make sure that the marked face of the wooden sheet (blue dot in the corner) is facing the mirror.
3. Hold the light torch (source of light) vertically above the slit arrow. Ensure that the slit arrow is uniformly illuminated.
4. Change the position of the wooden sheet until you obtain a clear image of the arrowhead tip on the lower surface (marked with the blue dot) of the wooden sheet. You should get a real, inverted and equal image of the arrow on the lower surface of the wooden sheet.

5. Measure the vertical distance between the tip of the arrowhead or its image and the base of the stand (the pole, P, of the mirror).. This distance (PR) is the real radius of curvature of the mirror. Repeat step 5 three times. Record your measurements in Table 3 in the answer sheet.
6. Find the value of the focal length of the concave mirror. .
7. Using the dropper provided, *carefully* pour sample "PHYS-A" on the reflective side of the mirror, Add enough water to cover the reflecting surface of the mirror.
8. Slowly, move the wooden sheet up and down until you get a real, inverted and equal image of the arrow on the lower surface of the wooden sheet.
9. Measure the vertical distance between the tip of the arrowhead or its image and the base of the stand (the pole, P, of the mirror). This distance is the apparent radius of curvature of the water-filled mirror SR\. Repeat the experiment two more times. Record your measurements in Table 3 in the answer sheet.
10. Clean and dry the mirror using the provided tissue papers.
11. Repeat the same experiment (steps 7 to 9) using sample PHYS-B and record your measurements in Table 3.
12. Assess the uncertainty using the precision of the measuring tool. (uncertainty in the ruler measurements equals the least measurable unit divided by 2).

Table 3. Data and calculations. <u>All answers are to be recorded in the yellow answer sheet.</u>

Measured distances (cm)	Trial 1	Trial 2	Trial 3	Mean ± uncertainty
For empty concave mirror (PR)				
For PHYS-A- filled mirror (SR\)				
For PHYS-B- filled mirror (SR\)				

Analysis and questions:

A. Find the focal length (*f*) of the concave mirror you used in this experiment.

$f \pm \Delta f =$

B. Determine the refractive index of sample PHYS-A with respect to the air in the form (n_A), where n_A symbolizes the refractive index of sample PHYS-A. Show your calculations in the answer sheet.

C. Determine the refractive index of sample PHYS-B with respect to the air in the form (n_B), where n_B symbolizes the refractive index of the sample PHYS-B.

Show your calculations in the answer sheet.

D. Based on your findings from the above method (Optics), identify samples PHYS-A and PHYS-B (circle the right answer in the answer sheet).

PHYS-A: Seawater/ desalinated water

PHYS-B: Seawater/ desalinated water

Second Method (Thermodynamics):

First, you will monitor the rise in temperature in desalinated water and seawater as you heat each sample until it reaches the boiling point. You will use this information to investigate the specific heat capacity of desalinated water and seawater.

Principle:

The specific heat capacity of a material describes the amount of energy required to raise the temperature of 1 gram of the material by 1 degree Celsius. The relevant formula is usually written as:

$$Q = m\ c\ \Delta T$$

Tools:

Unknown Samples	You will be supplied with *two* samples for this task labelled as: **PHYS-A, PHYS-B**.
Tools and Equipment	A 180 W Electric heater (Hot plate), alcohol thermometer, stopwatch, heat resistant gloves, two 250 mL conical flasks, Electronic balance.

SAFETY PRECAUTIONS:

A hot plate (an electric heater) will be used in this part of the task, be careful.

Procedure:

1. Fill a conical flask with 200 mL of PHYS-A sample and determine the mass (m) of the sample;
2. Set up the equipment as shown in Figure 2, ensuring that the thermometer is placed in such a way that it will measure water temperature, not the temperature of the conical flask. The thermometer should not be touching the flask;
3. Record the initial temperature of the sample. Place the conical flask on the heater. Switch the electric heater (hot plate) on, making sure that temperature knob is turned to maximum - BE CAREFUL;
4. Record the measured temperature every 60 seconds, until the sample begins to boil. Take *five* more readings after the sample is boiling;
5. Repeat the above steps using PHYS-B in a new conical flask;
6. For each time value used in your measurements, calculate the corresponding amount of energy transferred (Q) to the samples assuming that 50 % of the heat goes into water.

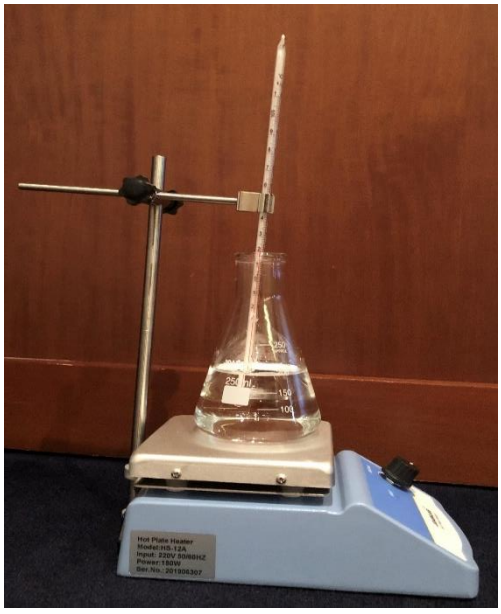


Figure 2. Experimental setup.

Table 4. Data collection sheet. All answers are to be recorded in the yellow answer sheet.

Time (s)	Temp (^{O}C) for PHYS-A	Temp (^{O}C) for PHYS-B	Energy transferred(J)

Analysis and questions:

A. Plot (on the same graph) the measured temperature (T) against time (t) for both samples.

B. From the graphs, deduce the gradients and intercepts of the initial straight-line portion on the T-axis.

$Slope_A$ = $Slope_B$ =

$Intercept_A$ = $Intercept_B$ =

Note: *A denotes sample* PHYS-A and *B denotes* PHYS-*B.*

C. Write an equation that describes how temperature varies with time before the boiling point is reached.

D. From your graphs deduce the boiling point, $T_{(boil)}$ of sample PHYS-A and sample PHYS-B.

$T_{(boil)}$ of sample PHYS-A:

$T_{(boil)}$ of sample PHYS-B:

E. Plot on another graph paper the measured temperature (T) against energy transferred (Q) for both samples.

F. What does the slope of the initial straight-line portion of each plot (drawn in the previous question) equal to? Circle the letter showing the correct answer:

I. mc

II. $\frac{1}{mc}$

III. c

IV. $\frac{1}{c}$

G. Using your measured data, deduce the specific heat capacity, c, for samples PHYS-A and PHYS-B. Give your answer with the appropriate units.

- the specific heat capacity, c, for sample PHYS-A.
- the specific heat capacity, c, for sample PHYS-B.

H. Based on your findings from the above method (thermodynamics), confirm the correct identity of samples PHYS-A and PHYS-B.

PHYS-A: Seawater/ desalinated water.

PHYS-B: Seawater/ desalinated water.

Task 3:

Determination of Water Hardness

Different types of water have varying amounts of dissolved salts that give water its unique taste. Sometimes, water can contain a high concentration of salts causing problems when used for drinking or washing. You might have experienced such a problem if you have taken a bath with water where you cannot get the soap to form bubbles. When this happens, water is said to be 'hard'. One of the measures of water quality is the degree of hardness.

In Qatar, water hardness may exceed the usual limits. A water sample has been sent to a desalination plant with the purpose of desalination. Following the desalination, this sample **(CHEM-A)** is now with you. Throughout the following task, you will be able to decide whether the plant has succeeded in their endeavor or further treatment is needed.

Principle:

Water hardness is mostly caused by the presence of the carbonate mineral deposits of divalent cations (e.g. Ca^{2+}, Mg^{2+}). Complexometric titration is one of the commonly used techniques for measuring water hardness.
EDTA (Ethylenediaminetetraacetic acid) is the chelating agent used in the titration. EDTA disodium salt (Na_2EDTA) solution is capable of forming a strong 1: 1 metal-EDTA complex with the divalent cations at pH around 10.

The indicator for titration of a metal ion with EDTA is usually a highly coloured dye - Eriochrome Black T (EBT) (blue colour solution) - that forms a complex of a different colour with the metal ion being titrated. The colour change during the titration of a metal ion with EDTA thus consists of two consecutive reactions:

$(Ca^{2+}$ or $Mg^{2+})$ + EBT → [Ca – EBT] (or) [Mg – EBT]
Hardness-salts indicator less stable complex

[Ca – EBT] (or) [Mg – EBT] + EDTA → [Ca – EDTA] (or) [Mg – EDTA] + EBT
less stable complex **magenta/violet** stable complex (colourless) **blue**

Hardness of water can be determined using formula below (consider density of water as 1.00 g/mL), and once the concentration in ppm is determined, it can be related to the hardness scale shown in Table 5.

$$\text{Total hardness (ppm } CaCO_3) = \frac{\text{Volume of EDTA used in titration (L) x Molarity of EDTA (mol/L) x molar mass of } CaCO_3 \text{ (g/mol) x 1000}}{\text{Volume of water sample (L)}}$$

Table 5. Water hardness scale in relation to water off the Qatari coast.

Degree of hardness	Hardness (ppm)
Soft	<50
Moderately soft	≥50 – <100
Slightly hard	≥100 – <150
Moderately hard	≥150 – <200
Hard	≥200 – <300
Very Hard	≥300

Task: Determine the total hardness of water sample (**CHEM-A**) based on a complexometric titration of calcium and magnesium with an aqueous solution of EDTA at pH value of 10.

Tools and Materials:

Unknown Sample	You will be supplied with *one* sample (70 mL) for this task labelled as: **CHEM-A**.
Tools	Stand with a rigid base and clamp, one 50.0 mL burette, two 10 mL pipettes, two pipette fillers. Two 250 mL conical flasks, one 500 mL beaker. A 10 mL measuring cylinder, one 50 mL measuring cylinder, a sheet of white paper.
Chemicals and Reagents	Na_2EDTA, 0.0100 M, 120 mL. Buffer solution (pH 10). Eriochrome black T indicator (EBT). Deionized water.

SAFETY PRECAUTIONS:

1. Fumes from the ammonia buffer (pH 10) might be an irritant. Please wear the provided mask in this step.
2. Ensure to wash your hands thoroughly at the end of the practical exam.

Waste Disposal:

All solutions must be disposed in the sink (the workstation has a built-in liquid waste disposal unit).

Procedure:

1. Rinse the clean burette -while on the stand- with few millilitres (3 – 9 mL) of 0.0100 M EDTA solution;
2. Fill the burette with the titrant (0.0100 M EDTA);
3. Pipette 10.0 mL of the water sample (CHEM-A) into a 250 mL conical flask;
4. Add 30 mL of deionized water using the measuring cylinder;
5. Fumes from the ammonia buffer (pH 10) might be an irritant. Please wear the provided mask in this step. Add 3 mL of the buffer solution. Make sure that you tighten the bottle cap following each use;
6. Add 4-5 drops of the EBT indicator solution;
7. The colour of the solution should turn to violet/magenta;
8. Titrate with EDTA solution until the colour of the solution changes from violet/magenta to light blue (with no hint of violet/magenta). The first *permanent* change to light blue colour is your endpoint;
9. Record the volume of EDTA (mL) to two decimal places in Table 6 in the answer sheet;
10. Repeat steps 3 – 8 two more times (at least) and report the results of what you judged as ***best three*** concordant titrations in Table 6.

Results: <u>All answers are to be recorded in the yellow answer sheet.</u>

Table 6. Determination of total hardness of water sample # CHEM-A.

	Run 1	**Run 2**	**Run 3**
Volume of water sample (mL)			
Initial volume of EDTA solution (V_i, mL)			
Final volume of EDTA solution (V_f, mL)			
Change in volume of the solution (ΔV, mL)			

Analysis and questions:

Based on data recorded in Table 6, answer the following questions in the answer sheet:

A. Calculate the average volume of EDTA solution (mL) used.

Average volume of EDTA solution used (mL) =

B. Calculate the % relative standard deviation (%RSD) for the volume of EDTA (mL) recorded in Table 6, knowing that *%RSD = (S*100)/average.*
Report your answer as Average ± %RSD in the answer sheet.

C. Using the **average** volume of EDTA solution, calculate the hardness of Sample CHEM-A. Show detailed calculations in the space provided in the answer sheet:

C1. Moles of EDTA =

C2. Moles of Ca^{2+} in the sample =

C3. Moles of Ca^{2+} per litre =

C4. Mass (g) of $CaCO_3$ in 1 litre =

C5. Water Hardness (ppm) using the formula under the Principle section =

D. Using the water hardness scale in Table 5, identify (by ticking) the type of water – Sample CHEM-A in the yellow answer sheet.