Indian Olympiad Qualifier in Junior Science (IOQJS) 2020-2021

conducted jointly by
Homi Bhabha Centre for Science Education (HBCSE-TIFR)
and
Indian Association of Physics Teachers (IAPT)

Part II: Indian National Junior Science Olympiad (INJSO)

Homi Bhabha Centre for Science Education (HBCSE-TIFR)

Date: January 17, 2021 Time: 15:45 – 17:45 hrs

Question Paper

Roll Number: | | | | | | | | | | | | | Maximum Marks: 100

Please Note:

- Check that the question paper has 12 printed sheets.
- Please write your roll number in the space provided above.
- Use of non-programmable scientific calculator is allowed.
- **The answer-sheet must be returned to the invigilator.** You can take this question paper with you.
- Section I of this question paper has 12 questions
  - For each question in this section, **only one** of the four options is a correct answer.
  - For each question in this Section, a correct answer will earn 3 marks, a wrong answer will earn (−1) mark, and an un-attempted question will earn 0 marks.
  - If you mark more than one option, it would be treated as a wrong answer.
- Section II contains 9 questions with multiple parts.
  - For questions requiring detailed solution or reasoning, an appropriate box is provided in the answer booklet. For such questions, marks will be awarded for showing the process involved in arriving at the answer, along with the final answer. Valid assumptions/approximations are perfectly acceptable. Please write your method clearly, explicitly stating all the reasoning / assumption / approximations.
  - Each question involving marking a statement as True/False carries 1 mark for correct answers and −0.5 mark for a wrong answer.

Useful Data

Acceleration due to gravity	$g \approx 10.0$ m / s^2
Avogadro constant	$N_A \approx 6.022 \times 10^{23}$ /mol
Atmospheric pressure	1 atm $\approx$ 101 325 Pa
Radius of the Earth	$R_E = 6.37 \times 10^6$ m
Population of India	$N_{P\,(\mathrm{Ind})} \sim 140.0$ crores
Latent heat of vaporization of water at 288 K	$L = 2.46 \times 10^6$ J / kg
Density of water	ρ (water) = 10^3 kg / m^3
Density of Ethyl alcohol	ρ (C_2H_5OH) = 789 kg / m^3
Density of Carbon tetrachloride	ρ (CCl_4) = 1,590 kg / m^3
Density of 0.15 M aqueous Potassium iodide	ρ (0.15 M KI) $\simeq$ 1,200 kg / m^3

Element	Atomic Mass	Atomic Number	Element	Atomic Mass	Atomic Number
H	1.01	1	Cl	35.45	17
C	12.01	6	K	39.09	19
N	14.00	7	Ca	40.07	20
O	15.99	8	Mn	54.93	25
F	18.99	9	Fe	55.84	26
Na	22.99	11	Zn	65.38	30
Mg	24.30	12	Ag	107.87	47
Al	26.98	13	I	126.90	53
S	32.06	16	Ba	137.33	56

pH value	0	3	6	7	10	12	14
Colour of pH paper	Red	Orange	Yellow	Green	Blue	Violet	Indigo
Nature of the solution	Acidic			Neutral	Basic		

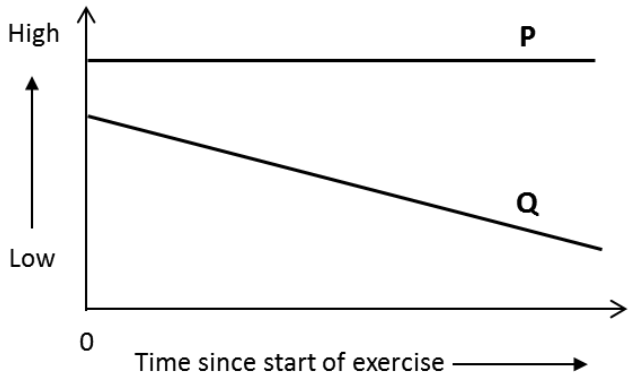
Section I

1. The autonomous nervous system regulates involuntary functions of the body and can be subdivided into the sympathetic and the parasympathetic nervous system. Both of these systems control the same group of body functions, but have opposite effects on the functions they regulate. The sympathetic nervous system prepares the body for intense physical activity like the fight-or-flight response. The parasympathetic nervous system has the opposite effect and relaxes the body and inhibits or slows many high energy functions. Which of the following involuntary effects in the body are brought about by the sympathetic nervous system during a fight-or- flight situation?

i. Increased salivation
ii. Increased digestion
iii. Loss of bowel and bladder control
iv. Body shivering
v. Crying
vi. Pupil dilation

A. i, ii and vi B. i, iv and v C. iii, iv and vi D. iii and v

2. When a person starts exercising, many body parameters change from the original state of rest. The trends in two such parameters are shown in the graph during the initial phase of exercise.



P and **Q** most likely represent:

A. **P**: carbon dioxide level in vein **Q**: oxygen level in artery.
B. **P**: breathing rate **Q**: carbon dioxide level in artery.
C. **P**: oxygen level in artery **Q**: carbon dioxide level in vein.
D. **P**: oxygen level in artery **Q**: oxygen level in vein.

3. Descriptions of four biological samples (I - IV) are given below.

I: Can be viewed using a light microscope with a total magnification of 1000X; possesses cell wall and does not possess mitochondria.
II: Can be seen using a light microscope with a total magnification of 100X; possesses cell wall and has a nucleus.
III: Needs electron microscope for viewing; can be found attached to the membrane system in the cytoplasm.
IV: Needs electron microscope for viewing; cannot replicate on its own, needs other specific cells for replication.

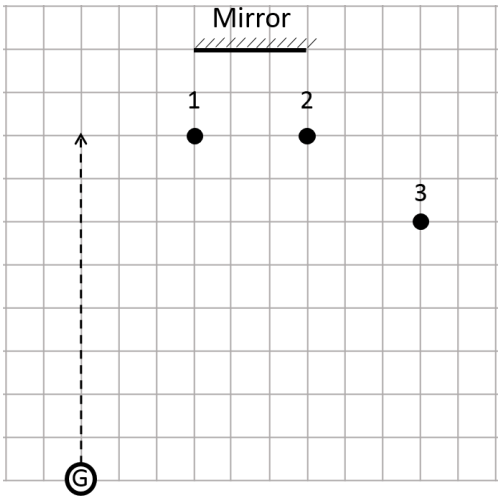
I, II, III, and IV respectively represent:

A. virus; plant cell; ribosome; bacteria. B. plant cell; bacteria; vacuole; virus.
C. bacteria; plant cell; ribosome; virus. D. bacteria; protist; plant cell vacuole; mitochondria.

4. Raja's mother collects all the kitchen waste every day and puts it in a pot. She then adds a few cut pieces of old papers, a spoonful of sour buttermilk and some soil. She covers the pots, and keeps it aside with intermittent mixing. After several days, it turns into a nutrient-rich compost to grow plants. In the context of decomposition in this composting process, the most appropriate statement among the following is

A. Paper acts as a good source of carbon while buttermilk gives the correct acidity to the mixture.
B. Soil acts as a good source of inorganic nitrogen while buttermilk is a good source of proteins.
C. Paper is a good source of carbon while buttermilk is a good source of starter bacteria.
D. Paper is a good source of fibre while buttermilk is a good source of fat.

5. A girl (G) walks into a room along the path shown by the dashed line (see figure on right). She tries to observe images of small toys numbered 1, 2, and 3 in the plane mirror on the wall.



The order in which she will see images of the toys is:

A. 3, 2, 1. B. 3, 2.
C. 1, 2, 3 D. 2, 3.

6. A heating element in the form of a wire with uniform circular cross sectional area has a resistance of 310 Ω, and can bear a maximum current of 5.0 A. The wire can be cut into pieces of equal length. The number of pieces, arranged suitably, so as to draw maximum power when connected to a constant voltage of 220 V, is

A. 7. B. 8. C. 44. D. 62.

7. Consider the following two statements:

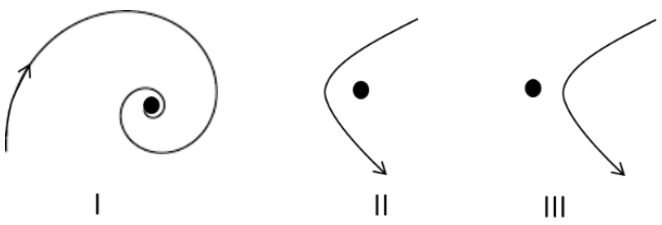
Statement S1: If you put 100 g ice at 0°C and 100 g water at 0°C into a freezer, which is maintained at –10°C, the ice will eventually lose the larger amount of heat.

Statement S2: At 0°C, water is denser than ice.

Choose the correct statement among the following.

A. Both S1 and S2 are true and S2 is the correct explanation of S1.
B. Both S1 and S2 are true but S2 is not the correct explanation of S1.
C. S1 is true but S2 is false.
D. S1 is false but S2 is true.

8. Consider the paths of (1) Halley's Comet near the sun, and (2) an alpha particle scattered by a nucleus. In the figures below, the dots represent the Sun/Nuclei, and the curves with arrows mark the paths of the comet/alpha particles schematically.



The correct statement about the trajectories is:

A. I represents trajectory for Halley's Comet and II for the scattering of alpha particles.
B. III represents trajectory for Halley's Comet and II for the scattering of alpha particles.
C. II represents trajectory for Halley's Comet and I for scattering of alpha particles.
D. II represents trajectory for Halley's Comet and III for scattering of alpha particles.

9. When water changes phase from liquid to vapor, some bonds are broken. The correct statement relating to this change is:

A. New bonds are formed between nearby H/H and O/O while H–O bonds break.
B. Hydrogen bonds between H_2O molecules are broken.
C. Covalent bonds existing within the H_2O molecules are broken.
D. Ionic bonds existing between H^+ ions and OH^- ions are broken.

10. Jyoti was asked by her mother to add a pinch of potassium permanganate to water in a container to disinfect it. As she added the crystals and observed the changes in water, the phenomena of diffusion came to her mind. She wrote the following statements. Identify the statement made by Jyoti that is **incorrect**.

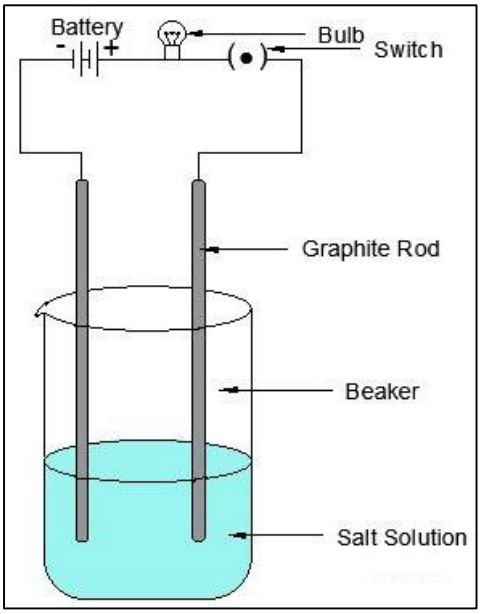
A. When the entire liquid is of uniform color, no further diffusion can be observed.
B. The diffusion gets completed almost instantaneously.
C. Diffusion will take place slower if the water is colder.
D. Maximum color in liquid originates from the bottom of the flask.

11. Ramen collected rain water and measured its electrical conductivity. He boiled the water for a few minutes. Then he covered the container and allowed the water to cool to room temperature. Electrical conductivity of water now measured was lower than that measured before boiling. The reason for this most likely is:

A. precipitation of $CaCO_3$ from the water during boiling.
B. removal of dissolved oxygen from the water.
C**.** removal of dissolved carbon dioxide from the water.
D. reaction of cationic species in the water with atmospheric oxygen.

12. Consider a setup in which two graphite rods are immersed in a 2 M NaCl (aq.) solution. The rods are connected to two terminals of a 9 V battery with a bulb in series as shown in the figure. Of the following, the change that will **NOT be observed** when the circuit is closed for a few minutes is:

A. The bulb will glow.
B. The pH of solution near the cathode will increase.
C. Oxygen gas would be generated near the +ve electrode which will oxidize the graphite electrode.
D. Total mass of liquid in the beaker will decrease.



Section II

13. (3 marks) A student was given 2.89 g of a mixture containing anhydrous $MgCl_2$ and KNO_3, and had to quantify amount of $MgCl_2$ in the mixture. The student uses excess $AgNO_3$ (*aq*) to precipitate the chloride ion as AgCl(*s*), and finds the mass of the AgCl precipitate to be 5.32 g. Calculate the mass percentage of $MgCl_2$ in the original mixture. (Atomic masses should be taken as per the data given.)

14. (12 marks) Iodine, an essential element for humans, is naturally present in some marine fishes, plants and ecosystems at large. Solubility of elemental iodine in water is negligible but is high in non-polar organic solvents. The most common form of iodine used in the diet of humans and animals is potassium iodide (KI), a white solid powder at room temperature, which is highly soluble in water.

14.1. In a chemistry laboratory period, 36 students of a class had to perform the following tests.

i. 0.5 gram KI is dissolved in about 5 cm^3 distilled water. A drop of this solution is put on a moist pH paper.

ii. 0.5 gram KI is dissolved in about 5 cm^3 distilled water. Part of this solution is mixed with lead (II) nitrate solution. The colour changes in the mixture are observed.

iii. 0.5 gram KI is put in a test tube containing about 5 cm^3 distilled water. Then they are to observe whether the test tube becomes hot or cool on mixing.

In test ii, a yellow precipitate is observed. In test iii, the test tube becomes colder as KI dissolves.

(a) Identify the colour imparted on pH paper in test i.

(b) Being very expensive, KI should be economically used. What is the minimum amount of KI (in grams) required for the complete class for carrying out the above three tests procedures? Write necessary calculations/reasoning needed to arrive at your answer.

14.2. An aqueous solution of KI treated with acidified solution of hydrogen peroxide (in sulphuric acid) gives a precipitate of Iodine crystals.

(a) Write the balanced molecular equation for the reaction**.**

(b) Identify the reducing agent in the reaction.

(c) The most appropriate option to separate iodine from the above mixture is:

A. filtration B. distillation C. steam distillation D. chromatography E. using a magnet

14.3. When solid KI is heated in an open ***dry test tube***, a gas is liberated from the test tube.

(a) What is the colour of the gas?

(b) After the gas evolution stops, what remains in the test tube? Write its chemical symbol/formula (if mixture, write formulae of components) and its state (solid/liquid).

(c) The reaction can be classified as (identify the correct option(s)):

A. thermal combination B. thermal decomposition

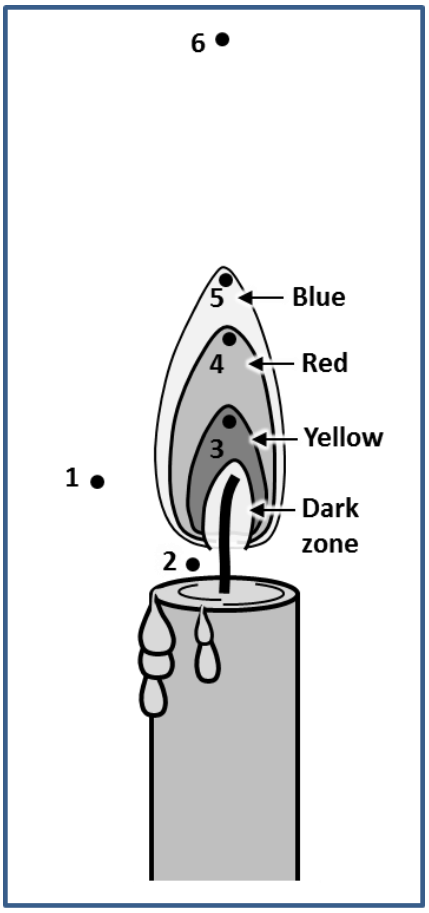
C. double displacement D. displacement reaction

14.4. Tincture iodine is an antiseptic, also effective in inactivating the novel coronavirus. It is prepared by dissolving 20 g of Iodine and 25 g of KI in 500 mL alcohol and then adding distilled water to make the volume 1000 mL. In this process, iodine combines with I^- to produce I_3^- species.

Sumit and Rekha were separately preparing tincture iodine using the above procedure. Sumit was working hurriedly, as he wanted to join a birthday party. By mistake, he added carbon tetrachloride in the flask instead of alcohol. At the end of the procedure, two immiscible liquid layers appeared in his flask. Sumit shook the flask vigorously and kept it for some time. The two layers remained separate. He observed that the lower layer was strongly colored, while the upper layer had a faint colour different from the lower layer. Rekha followed the protocol perfectly and got a homogenous mixture.

Identify the compositions of the top and the bottom layers in Sumit's flask.

15. (8 marks**)** Flame is a hot bright stream of burning gases. Flames have different structures and properties depending on fuel and burning conditions. The attached figure (drawn approximately to scale) shows a candle flame burning in open air in which three regions are distinctly visible surrounding a dark zone: an innermost zone that is pale yellow in colour, surrounded by a red zone, with a bluish envelop at the outside. Points **1** - **6** represent different locations in the inside and surrounding region of the flame. Consider wax to have chemical formula $C_{24}H_{50}$.



15.1. Among points **1** - **6**, identify

(a) the hottest point.

(b) the coldest point.

(c) the point where water vapour concentration is the highest.

15.2. From the following list, identify two substances that are present at point **3** but not at point **6**. Also write chemical equations for the reactions causing removal of these substances.

List: Oxygen, Nitrogen, Carbon, Wax, Carbon dioxide, Carbon monoxide, Water.

15.3. The space at point **2** prominently has (identify the correct option):

A. only air.

B. air with freshly evaporating wax vapour.

C. air with extra carbon dioxide released from combustion.

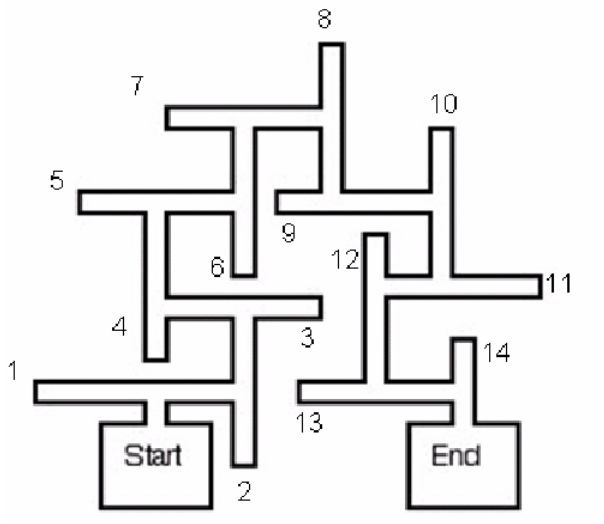
D. oxygen rich air (as oxygen concentration has locally increased due to diffusion).

15.4. Another flame used in laboratories is produced from Bunsen burner. It is used for heating, combustion, sterilisation processes, etc. By adjusting the ratio of gas (fuel) and air in Bunsen burner, it is possible to get a stable blue flame, which is largely non-luminous. Shlok was given two different organic compounds: naphthalene ($C_{10}H_8$) and citric acid ($C_6H_8O_7$). He burned 1.0 g of each compound separately in a porcelain piece in a blue Bunsen burner flame.

For which of the two compounds, the flame would emit more yellow light? Write reason for your answer, along with necessary supporting calculations/arguments.

16. (8 marks) A famous experiment performed by Tolman and Honzik (in 1930) studied the behaviour of rats in a complex maze (shown in the figure) for a period of 17 days. The rats had to find their way around the maze once every day. All rats were healthy and were given regular meals throughout the experiment.

The rats were divided into 3 groups, which were treated as follows on reaching the end of the maze.



Group 1:

Day 1 -17: every time the rats reached the end, they were given additional food.

Group 2:

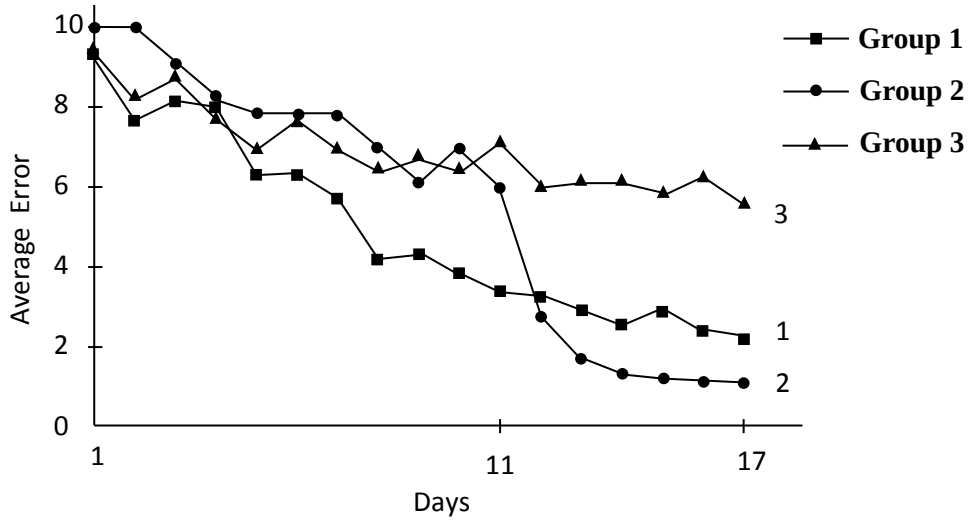
Day 1 -10: every time the rats reached the end, they were removed from the maze.

Day 11-17: every time the rats reached the end, they were given additional food.

Group 3:

Day 1-17: every time the rats reached the end, they were removed from the maze.

The average number of errors (any deviation from the shortest correct path to reach the end) observed for each group of rats is shown in the graph below.



16.1. A few statements are listed below. Based on the results of the experiment, identify each of the statements as True or False.

(a) Rats need good nutritional status to perform well in the maze.

(b) Result shows characteristic stimulus (maze) - response (reaching the end) behavior which is genetically determined and hence not changeable.

(c) The find of end of the maze is by trial and error method and not due to learning.

(d) Rewarding the rats has improved the end results.

(e) There was active learning happening in rats in group 2 even before day 11.

16.2. What response can be expected if the rats in the group 1 were kept hungry before the experiment? Assume that all other conditions in the above experimental setup remain the same. Choose the most appropriate option from choices below and justify your choice based on the experimental observations presented above (only). Also give reasons for rejecting the other three options.

A. Overall rise of line 1 above line 3.

B. Increase in errors as the experiment proceeds.

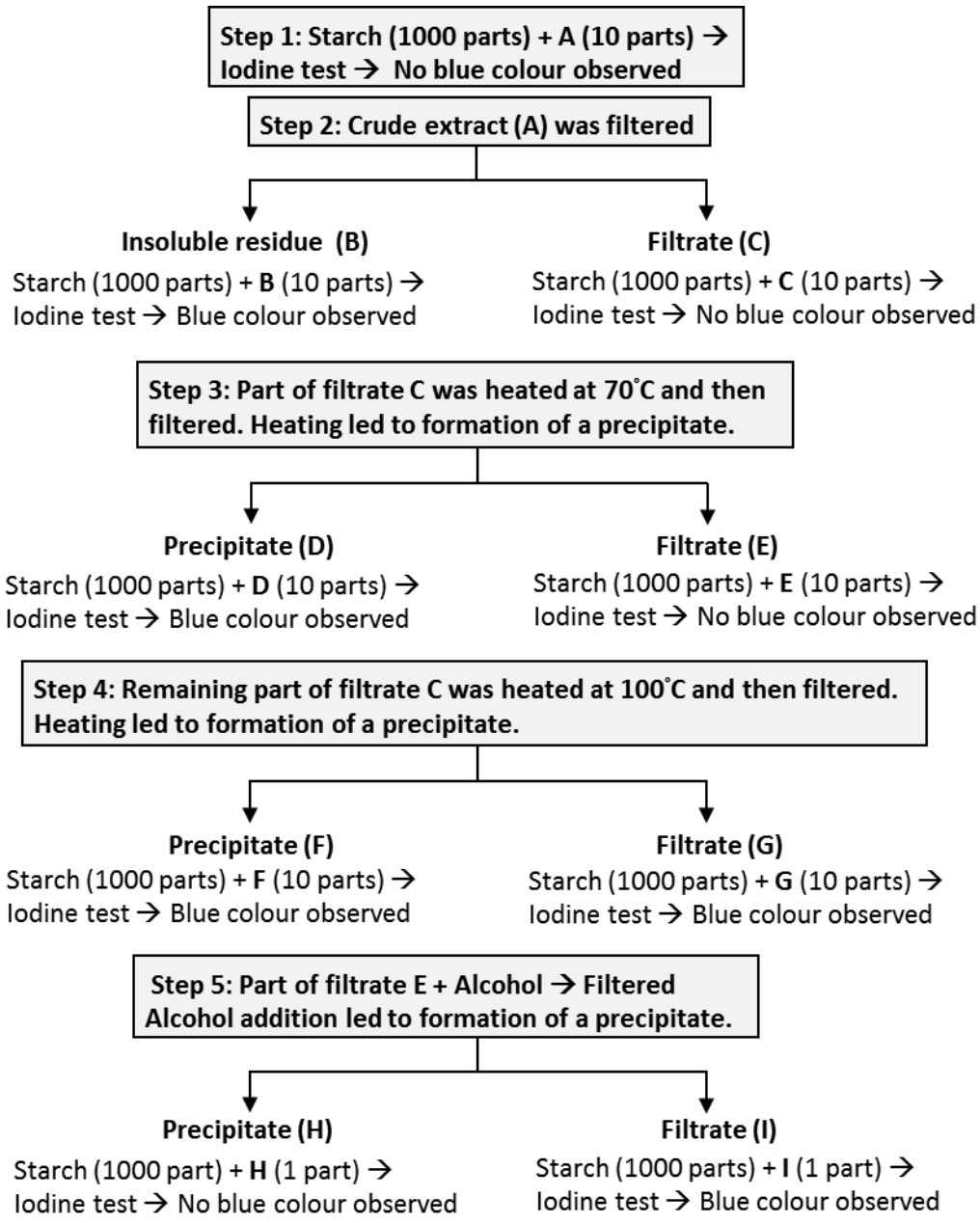
C. Steeper decrease in the line 1 in lesser time.

D. Same response as line 3 in the graph.

17. (7 marks) In the early nineteenth century, two scientists Payen and Persoz ground barley seeds in water to prepare a crude extract (**A**). The scientists then carried out a series of treatments on the extract **A**. At every step, iodine tests were carried out as follows.

Iodine test: Mixture (Starch + sample) → Wait for 10 mins → Add iodine → Check for colour changes

The different steps of treatment and the results recorded are shown in the flow chart below.



17.1. Blue colour indicates: (identify the correct option)

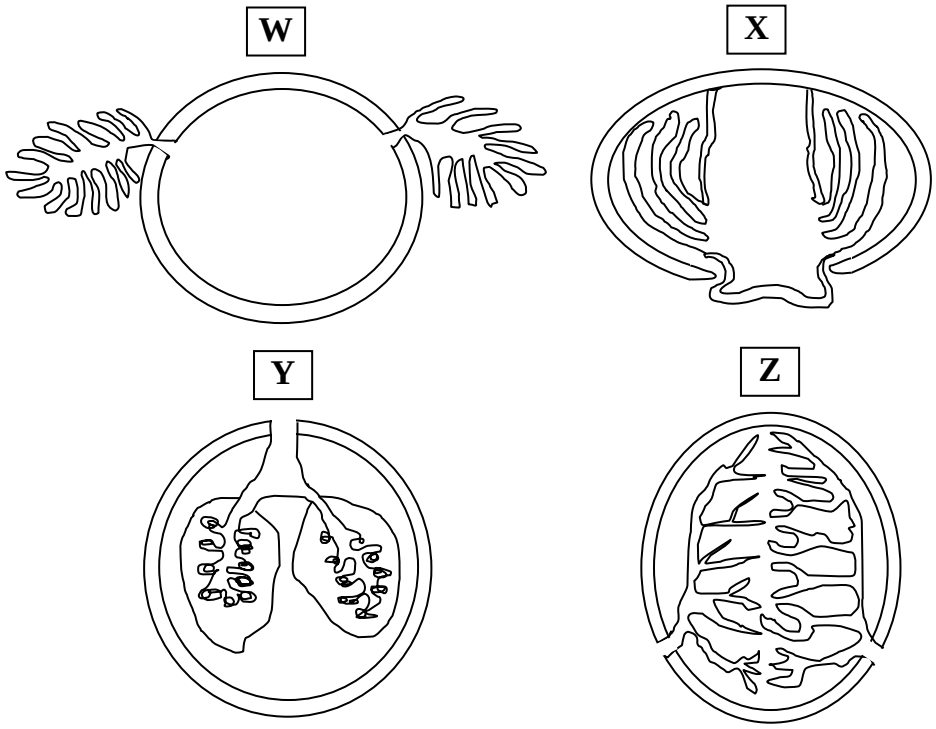
A. that starch is a polymer of glucose units.
B. that starch is digested into small units of glucose.
C. glucose units released from starch have formed a complex with iodine.
D. iodine is trapped in the intact polymer of starch.

17.2. Based on the observations, identify each of the following statements as True or False.

(a) Barley seeds contain a substance that converts glucose to starch.
(b) Barley seed coat contains a substance that can convert starch to glucose but it gets destroyed by heat.
(c) The substance present in barley seeds is water soluble and breaks starch into small units.
(d) The process of heating up to 70°C enhances the chemical activity of the barley filtrate but heating above 70°C inactivates it.

17.3. Which of the preparation/s (**A** to **I**) indicate/s the presence of the 'active substance' being analyzed in barley?

18. (7 marks) Different types of respiratory organs in animals occupying different habitats are represented in the figures (**W** – **Z**) below.



18.1. The organs most likely belong to: (choose from the options) cockroach, prawn, tadpole, and rabbit?

The Fick's law of diffusion shows how various factors influence the rate of diffusion and is represented as:

$$Q = D\,A\,(P1 - P2) / L$$

Where, Q = rate at which a gas such as O_2 diffuses between two locations

D = diffusion coefficient, which is characteristic of the diffusing substance (e.g., a gas), the medium and the temperature

A = cross sectional area over which the gas is diffusing

$P1$ and $P2$ are the partial pressures of the gas at the two locations

L = path length or distance between the two locations

18.2. If the temperatures of the habitats, in which the four animals having the organs of type **W** – **Z** live, are the same, then, based on the medium used for gas exchange, the value of D would be higher for animals possessing respiratory organs of the types (**a**)_____ as compared to animals with organs of types (**b**)_____(choose from **W** – **Z**).

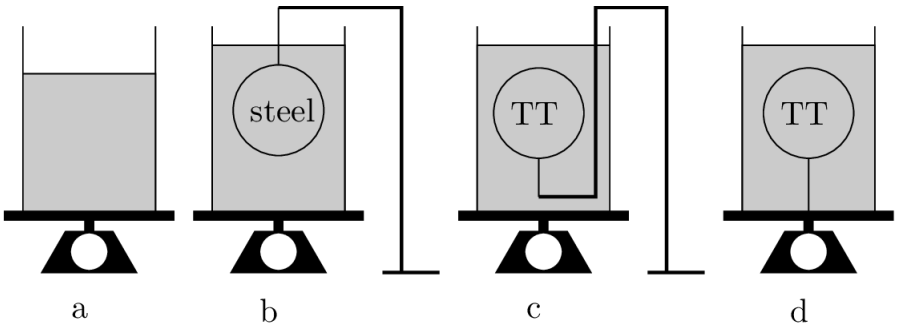
18.3. Two features of respiratory organs in animals are listed in Column I in the given table. Fill in

- column II with the appropriate factor from Fick's law equation that will be affected by the feature mentioned in column I,
- column III with the effect that the feature will have on the factor mentioned in Column II, and
- column IV with the corresponding effect on the rate of diffusion (Q).

(Marks will be given only for completely correct row.)

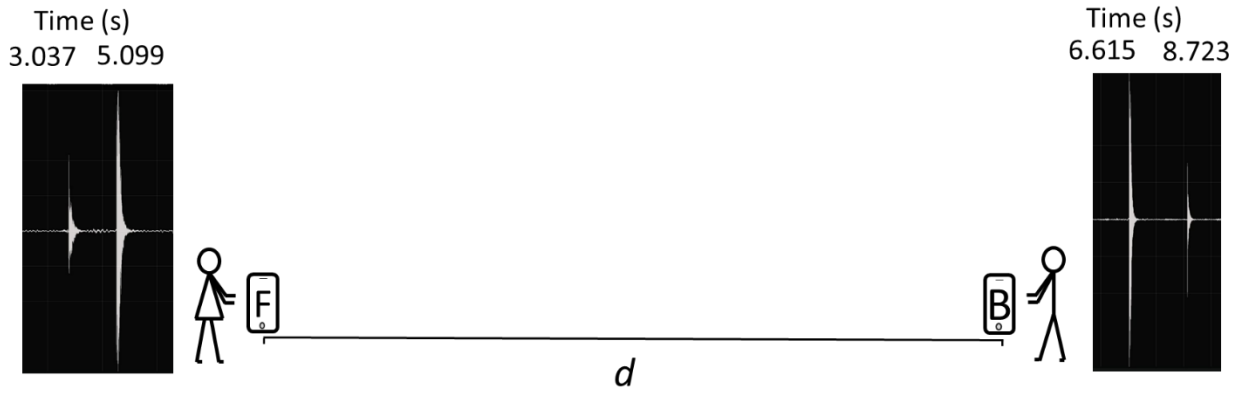
Column I	**Column II**	**Column III**	**Column IV**
Feature	**Factor affected (*D* / *A* / *P1* or *P2* / *L* or none)**	**Effect (increase/ decrease/ no change)**	**Effect on *Q* (increase/ decrease/ no change)**
1. Highly branched and folded extensions	–	–	–
2. Presence of very thin-walled tissues	–	–	–

19. (7 marks) Four identical beakers, as shown below, contain the same amount of water. Beaker `a' contains only water. A steel ball (mass 0.800 kg) is held submerged in the beaker `b' by a string from above. A same-sized plastic TT ball (mass 0.020 kg) is held submerged in beaker `c' by a string attached to a stand from outside, as shown in the figure. Beaker `d' contains same sized TT ball held submerged from a string attached to the bottom of the beaker. The volume of each ball is 10^{-4} m^3. These beakers (without stands) are placed on weighing pans and register readings W_a, W_b, W_c and W_d for a, b, c and d, respectively.



If $W_a = 1\,kg$, then obtain $W_b, W_c,$ and W_d. Show the main steps of your calculations. For calculation purpose, ignore the part of stand and the thread submerged in water.

20. (6 marks) Smartphones can be used to perform simple experiments related to sound. There are various apps which record the intensity of an audio signal. An app (WaveEditor™ here) displays the audio signal in the form of a wave, whose amplitude is proportional to the loudness of the audio signal.



Two students Fatima (F) and Bharat (B) conduct a simple experiment using smartphones. In an open field, both place their smartphones at a distance *d* from each other as shown in the figure. They stand next to their smartphones, and clap one after another. The audio signals from the claps are digitally recorded by WaveEditor™ and the output produced on their smartphone screens are shown next to their sketches. Note that the figure is not to scale. The time mentioned above the screen image is the time of the peak amplitude for each clap's audio signal received in their phones, respectively. They determine the speed of sound from this experiment to be 363 m/s.

Calculate the distance d (in m). Show the main steps of your calculation.

21. (6 marks) With about half of its surface always having day, Earth constantly receives heat from the Sun and maintains an average temperature of 288 K. From this heat, an average power of 4.3×10^{16} W goes into the evaporation of water. The water evaporated from the Earth finally precipitates over its surface. Suppose one collects this water for one year and the thickness of this water shell is *h* over the surface of the Earth; this value in meters is the well-known average annual rainfall on the globe. For the following two questions, make suitable assumptions wherever needed.

21.1. Estimate h.

21.2. The fresh water requirement is about 6800 l/day per head, which includes domestic water usage and water used for irrigation and industry. Estimate the ratio of water requirement for the population of the world and the total water received through rain over the land annually.