IOQJS-2021_Code-53

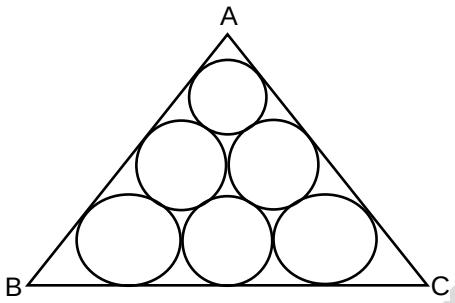
Number of Questions: 32 **Time: 1 Hour** **Max Marks: 120**

INSTRUCTIONS

Part-A-1	Q.1 to Q.24	(SCQ)
Part-A-2	Q.25 to Q.32	(MCQ)

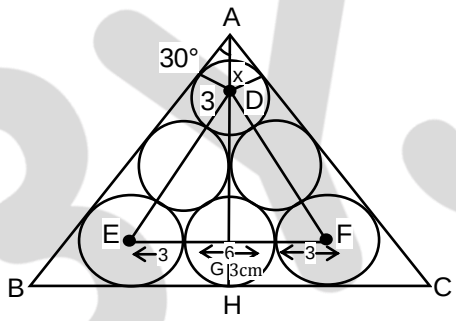
PART-A-1

1. Six circles each of radius 3cm are inscribed in an equilateral triangle ABC such that they touch each other and also touch the sides of the triangle as shown in the adjacent figure height of triangle ABC is



(A) $6(2\sqrt{3}+3)$ (B) $3(2\sqrt{3}+6)$ (C) $3(2\sqrt{3}+3)$ (D) $6(2+\sqrt{3})$

Sol. **(C)**



ABC is an equilateral triangle.

We join centers of circle and form equilateral triangle DEF with side 12 cm.

Height DG = $\frac{\sqrt{3}}{2}\times 12$

$= 6\sqrt{3}$

AD $\Rightarrow \sin 30° = \frac{3}{x}$

x = 6 cm

Height of triangle ABC = AD + DG + GH

$= 6 + 6\sqrt{3} + 3$ cm

$= 9 + 6\sqrt{3}$

$= 3(3+2\sqrt{3})$

2. Find the remainder when x^{51} is divided by x^2-3x+2

(A) x (B) $\left(2^{51}-2\right)x+2-2^{51}$

(C) $\left(2^{51}-1\right)x+2-2^{51}$ (D) 0

Sol. **(C)**

$x^{51} = (x^2 - 3x + 2)\, g(x) + r(x)$

$x^{51} = (x - 2)(x - 1)g(x) + (ax + b)$

degree of $r(x)$ < degree of division

On putting $x = 1$,

$1^{51} = a + b$

$a + b = 1$ .....(1)

Now let us put $x = 2$,

$2^{51} = 2a + b$ ……(2)

(2) – (1)

$a = 2^{51} - 1$

Putting the value of 'a' in equation (1),

$2^{51} - 1 + b = 1$

$b = 2 - 2^{51}$

$r(x) = ax + b$

$= (2^{51} - 1)\, x + (2 - 2^{51})$

3. If $\frac{3}{x-2}<1$, where x is a real number, then

(A) $2<x<5$ (B) $x<2 \text{ or } 5<x$ (C) $x<-2 \text{ or } x>5$ (D) None of these

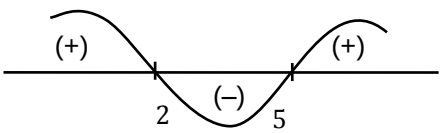
Sol. **(B)**

$$\frac{3}{x-2}-1<0$$

$$\frac{3-x+2}{x-2}<0$$

$$\frac{5-x}{x-2}<0$$

$$\frac{x-5}{x-2}>0$$



$x \in (-\infty, 2) \cup (5, \infty)$

So, $x < 2$ or $5 < x$

4. If $x^2+ax+b=0$ and $x^2+bx+a=0$ have one common root, then

(A) $a+b=0$ (B) $a+b=1$ (C) $a+b=-1$ (D) $a^2+b^2=1$

Sol. **(C)**

$x^2 + ax + b = 0$ ...(i)

$x^2 + bx + a = 0$ ...(ii)

Both have a common root α.

$$\frac{\alpha^2}{a^2-b^2} = \frac{\alpha}{b-a} = \frac{1}{b-a} \quad \text{...(iii)}$$

From equation (ii) and (iii),

$\alpha = 1$

From (i) and (ii),

$$\alpha^2 = \frac{(a+b)(a-b)}{b-a}$$

$$\frac{(1)^2}{(a+b)(a-b)} = \frac{1}{(a-b)}$$

$a + b = 1$

5. If $100^{25}-25$ is written in decimal notations, then the sum of its digits is

(A) 444 (B) 442 (C) 424 (D) 422

Sol. **(A)**

$100^{25} - 25$

$(10^2)^{25} - 25$

$10^{50} - 25$

9999 ---------- 75

48 times

Digit sum = $9 \times 48 + 7 + 5$

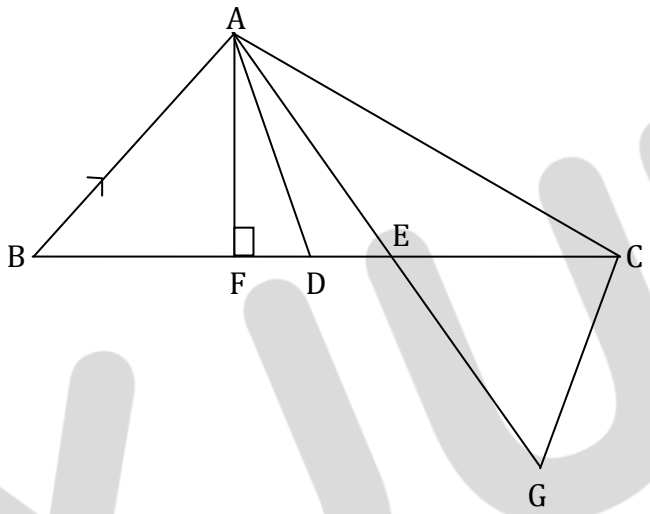
$= 432 + 12$

$= 444$

6. ABC is a triangle. The bisector of angle A meets BC in D. The relation between AD, AB and AC is

(A) $AD > \sqrt{AB \cdot AC}$ (B) $AD > AB.AC$ (C) $AD = \sqrt{AB \cdot AC}$ (D) $AD < \sqrt{AB \cdot AC}$

Sol. **(D)**



$$\frac{AB}{AC} = \frac{BD}{CD}$$

Thus, BD < CD and D lies to the left of E.

In ΔABC, $\angle B > \angle C$

$\angle A + \angle B + \angle C = 180°$

$\angle A + 2\angle C < 180$

$\Rightarrow \frac{\angle A}{2} < 90° - \angle C$

In ΔAFD and ΔAFE,

AD < AE

$\Delta ABE \cong \Delta GCE$

Then, CG = AB and AG = 2AE

From ΔACG,

$AB + AC > 2AE > 2AD \Rightarrow \frac{AB+AC}{2} > AD$

Now, $ar\Delta ABC = \frac{1}{2} AB.\ AC\ sinA$

$= AB.\ AC \sin\frac{A}{2}\cos\frac{A}{2}$

$ar\Delta ABD = \frac{1}{2} AB.AD \sin\frac{A}{2}$

$ar.\ \Delta ACD = \frac{1}{2} AC.AD \sin\frac{A}{2}$

Thus, we have

$AB.\ AC\ \sin\frac{A}{2}\cos\frac{A}{2} = \frac{1}{2} AD \sin\frac{A}{2}(AB+AC)$

By simplification,

$AB.AC\ \cos\frac{A}{2} = AD\ \frac{(AB+AC)}{2}$

$\because \frac{AB+AC}{2} > AD$

$AB.\ AC \cos A/2 > AD^2$

$0 < \cos\frac{A}{2} < 1$

$AB.\ AC > AD^2$

7. If in a wheat mutant, the length of chromosome 1B was found to be 6.7μm, instead of 5.0 μm, approximately how many additional base pairs are incorporated in the mutant chromosome?

(A) 0.5×10^4 bp (B) 5×10^4 bp (C) 1.7×10^4 bp (D) 5.78×10^4 bp

Sol. **(A)**

Wheat Mutant

Given → Length of chromosome IB

→ 6.7 μm = new length

→ 5.0 μm = old length

Change in length after mutation = 6.7 – 5.0 μm = 1.7 μm

→ 3.4 Å is the length between any two base pairs.

→ 3.4×10^{-10} meter

→ $3.4 \times 10^{-10} \times 10^{6}\mu m = 3.4 \times 10^{-4}\mu m$

→ $3.4 \times 10^{-4}\mu m \rightarrow$ 1 Base pair

→ $1\mu m \rightarrow \frac{1}{3.4\times10^{-4}}$ Base Pair

→ $1.7\ \mu m \rightarrow 1.7\times\frac{1}{3.4\times10^{-4}}$ Base pair

$= \frac{1.7}{3.4}\times10^4$ Base pair

$= 0.5 \times 10^4$ Base Pair

→ So, the correct option is A.

8. Considering following characteristics, identify the correct inheritance pattern from the given options.

- The most affected individuals are male.
- Affected sons result from the female parents who are either affected or who are known to be carriers because they have affected brothers, fathers or maternal uncles.
- Affected daughters are born to affected fathers and either affected or carrier mother
- The sons of affected mothers should be themselves affected.
- Approximately, half the sons of carrier mothers should be affected.

(A) Autosomal Recessive Inheritance (B) Autosomal Dominant Inheritance

(C) Sex-Linked Recessive Inheritance (D) Sex-Linked Dominant Inheritance

Sol. **(C)**

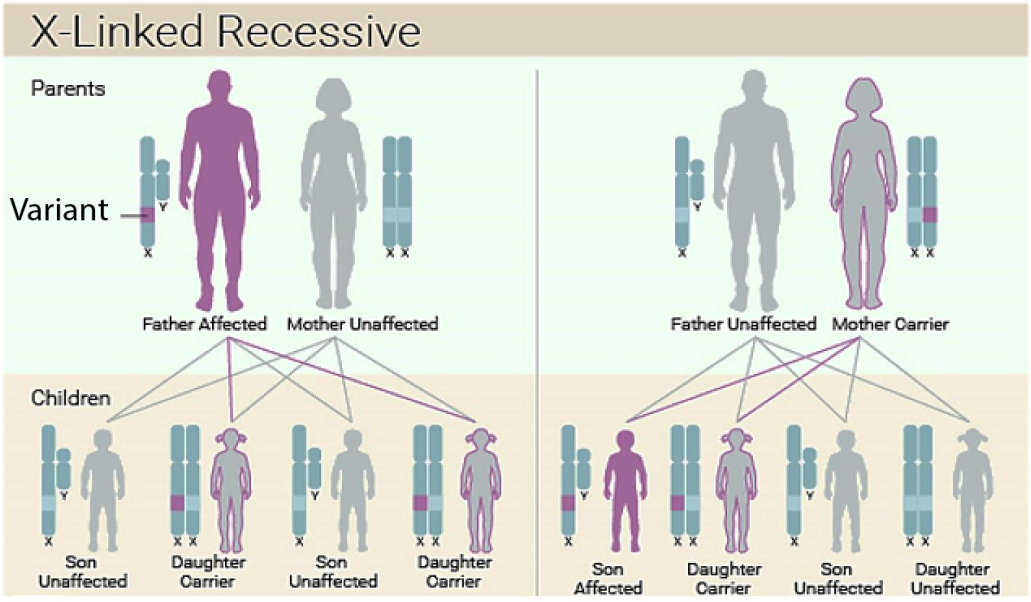
X-linked recessive inheritance is a mode of inheritance in which a mutation in a gene on the X chromosome causes the phenotype to be always expressed in males. A male carrying such a mutation will be affected, because he carries only one X chromosome.

(1) Males with an X-linked recessive disorder always inherit the disease-associated allele from their mother.

(2) Females (who have two X chromosomes) must have a mutation on both X chromosomes in order to be affected with the condition. If only the father or the mother has the mutated X-linked gene, the daughters are usually not affected and are called carriers because one of their X chromosomes has the mutation but the other one is normal.

(3) Sons will be affected if they inherit the mutated X-linked gene from their mother. Fathers cannot pass X-linked recessive conditions to their sons.

(4)



9. The transpiration pull is maximum under which of the following conditions?

(A) Closed stomata, low light intensity, humid air

(B) Open stomata, dry air, moist soil

(C) Open stomata, dry air, dry soil

(D) Open stomata, high humidity in air, moist soil

Sol. **(B)**

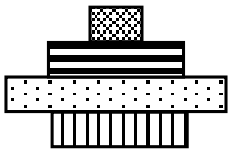
Environmental factors that affect the rate of transpiration-

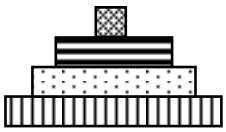
a) **Stomata-** When stomata are open, transpiration rates increase; when they are closed, transpiration rates decrease. Transpiration occurs through the stomatal apertures, and can be thought of as a necessary "cost" associated with the opening of the stomata to allow the diffusion of carbon dioxide gas from the air for photosynthesis.

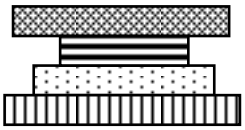
b) **Humidity-** The rate of diffusion of any substance increases as the difference in concentration of the substances in the two regions increases. When the surrounding air is dry, diffusion of water out of the leaf goes on more rapidly.

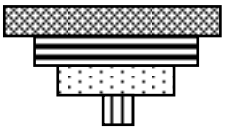
c) **Soil-** Plants cannot continue to transpire without wilting if the soil is very dry because the water in the xylem that moves out through the leaves is not being replaced by the soil water. This condition causes the leaf to lose turgor or firmness, and the stomata to close.

10. In a marine ecosystem with rich diversity of fauna which of the following images would be a correct representation of pyramid of biomass?

(A) 

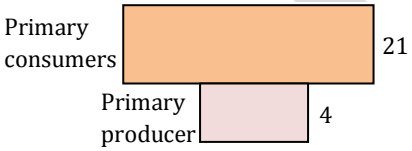
(B) 

(C) 

(D) 

Sol. **(D)**

Reason why zooplankton are higher than phytoplankton:-



[A] Lifespan :-

(i) Biomass of zooplanktons is higher than that of phytoplanktons as the life span of former is longer and latter multiply much faster though having shorter lifespan.

(ii) A number of generations of phytoplanktons may thus be consumed by single generation of zooplanktons.

(iii) Biomass of fish may be larger as fishes are large in size with longer lifespan and a number of generations of zooplanktons can be consumed by fishes.

[B] Reproduction- In open waters of aquatic ecosystems, the biomass primary consumers (zooplankton) can exceed that of producers. The zooplankton eat the Producers (phytoplankton) as fast as they reproduce, so their population is never very large.

Small standing crop of phytoplanktons supports the large standing crop of zooplanktons.

11. *Curcuma longa*, *Azadirachta indica*, Basmati Rice and Indian Ginseng are all related to which of the following concepts?

(A) Bioterrorism (B) Biomagnification

(C) Biopiracy (D) Biodegradation

Sol. **(C)**

Biopiracy:-

(i) Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

(ii) Most of the industrialised nations are rich financially but poor in biodiversity and traditional knowledge. In contrast, the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources. Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort and expenditure during their commercialisation.

(iii) In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent. Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric (***Curcuma longa)*** and neem (***Azadirachta indica***)

Bioterrorism- Intentional release of virus, bacteria or other germs. Example-*baccilus – anthracis.*

Biomagnification- (Bioamplification) Increase in concentration of toxin, successively higher level in food chain.

Biodegradation- Naturally occurring breakdown of material by micro organism such as bacteria and fungi.

12. Read the following criteria carefully.

- Slow evolutionary change relative to similar entities.
- Gross similarity to an ancestral fossil.
- Very low taxonomic richness at present as compared to the past.
- Phylogenetic inference of specific characters as plesiomorphic.
- Phylogenetic inference of a genealogical divergence between other groups that diverged in the distant past.
- Known in the fossil record before being discovered alive.

These criteria can be used to categorize a group of organisms most probably into

(A) Connecting links (B) Living fossils

(C) Endangered species (D) Extinct species

Sol. (B)

Living fossils have two main characteristics, although some have a third:

1. Living organisms are members of a taxon that has remained recognizable in the fossil record over an unusually long time span.
2. They show little morphological divergence, whether from early members of the lineage, or among extant species. (slow evolutionary change relative to the similar entities)
3. They tend to have little taxonomic diversity (very low taxonomic richness at present as compared to the past)
4. Exceptionally, little change throughout a long fossil record, gives the impression that the extant taxon had remained identical through the entire fossil and modern period. (known in the fossil record before being discovered live)
5. Living fossil being a surviving representative of an archaic lineage does not imply that it must retain all the "primitive" features; plesiomorphies (“near form”) of its ancestral lineage (pedigree).

So, the correct answer is living fossil.

13. Gravitational collapse is the contraction of an astronomical object under its own gravity. This draws the matter inwards towards the centre of gravity. A neutron star is an example of the collapsed core of a giant star. A certain neutron star of radius 10km is of mass $1.5M_{\odot}$. The acceleration due to gravity on the surface of the neutron star is nearly

(A) $2.0\times10^{8}\,m/s^2$ (B) $2.0\times10^{12}\,m/s^2$

(C) $2.6\times10^{16}\,m/s^2$ (D) $2.6\times10^{20}\,m/s^2$

Sol. **(B)**

Given That,

R = 10 km = 10000m

The gravitational force between two objects is

Given by;

$$F=\frac{G\,M_1M_2}{R^2}=\frac{G\,M_nM_s}{R^2};$$

M_n = mass of neutron

M_s = mass of sum

G = universal gravitational constant

$$\because g=\frac{GM_s}{R^2}$$

$$\Rightarrow\ g=\frac{6.67\times10^{-11}\times1.5\times1.99\times10^{30}}{10^{8}}$$

$$\Rightarrow\ g = 6.7\times1.5\times2\times10^{11}$$

$$\Rightarrow\ g = 20\times10^{11}$$

$$\Rightarrow\ g = 2\times10^{12}\ m/sec^2$$

14. The tympanic membrane (ear drum) is a very delicate component of the human ear. Typically, its diameter is 1cm. The maximum force that the ear can withstand is 2.5N. In case, a diver has to enter the sea water of density $1.05\times10^3\,\text{kg/m}^3$ without any protective gear, the maximum safe depth for the diver to go into water is about

(A) 12m (B) 9m (C) 3m (D) 1.5m

Sol. **(C)**

D = 1 cm

$\Rightarrow$ $R = \frac{1}{200}\text{m}$

F = 2.5 N

$\rho = 1.05 \times 10^3\ \text{kg/m}^3$

$\because$ $p = \rho gh$

$\Rightarrow$ $\frac{F}{A} = \rho qh$ $\Rightarrow$ $h = \frac{F}{A\rho g} \Rightarrow h = \frac{F}{\pi r^2 \rho q}$

$$\Rightarrow h = \frac{2.5\text{N}}{3.14\times\left(\frac{1}{200}\text{m}\right)^2\times1.05\times\frac{10^3\text{kg}}{\text{m}^3}\times\frac{9.8\text{m}}{\text{sec}^2}}$$

$$\Rightarrow h = \frac{2.5\text{N}}{3.14\times(0.005\text{m})^2\times1.05\times10^3\text{kg/m}^3\times9.8\text{m/sec}^2}$$

$\Rightarrow$ h = 3.125 m

$\Rightarrow$ h$\simeq$ 3 m

15. A nuclear reactor is working at 30% efficiency (i.e. conversion of nuclear energy to electrical energy). In this reactor, $^{235}_{92}U$ nucleus undergoes fission and releases 200 MeV energy per atom. If 1000kW of electrical power is obtained in this reactor, then the number of atoms disintegrated (undergone fission) per second in the reactor is:

(A) 1.04×10^{17} (B) 6.5×10^{12} (C) 3.125×10^{12} (D) 3.25×10^{32}

Sol. **(A)**

Given efficiency (η) = 30% ...(1)

Energy per atom = 200 MeV

$= 20 \times 1.6 \times 10^{-19} \times 10^{6}$ ... (2)

Electrical power = 1000 kW = 10^6 W ... (3)

Now from equation (1), (2) and (3),

$$\frac{30}{100} = \frac{10^6}{n\times200\times1.6\times10^{-19}\times10^6}$$

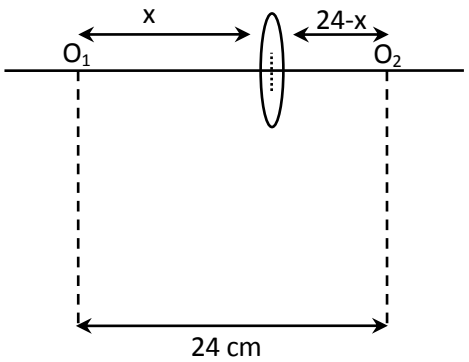
$$\Rightarrow \frac{30}{1} = \frac{1}{3.2\times10^{-19}\times n}$$

$$\Rightarrow n = 1.04 \times 10^{17}$$

16. Two illuminated point objects O_1 and O_2 are placed at a distance 24cm from each other along the principal axis of a thin convex lens of focal length 9cm such that the images of both the objects are formed at the same positions. Then, the respective distances of the lens from O_1 and O_2 (in cm) are

(A) 12 and 12 (B) 18 and 6 (C) 14 and 10 (D) 16 and 8

Sol. **(B)**



Given that focal length of a convex lens = 9 cm

Let the first object be at a distance x from the convex lens.

By using the lens formula i.e., $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

We get , $\frac{1}{v}-\frac{1}{-x}=\frac{1}{9} \quad \Rightarrow \frac{1}{v}=\frac{1}{9}-\frac{1}{x}$ ...(1)

Now for second object,

$$\frac{1}{-v}-\frac{1}{-(24-x)}=\frac{1}{9} \quad \Rightarrow \frac{1}{v}-\frac{1}{24-x}=\frac{-1}{9}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{24-x}-\frac{1}{9} \quad \text{...(2)}$$

$\because$ Image is formed at the same distance from the lens for both the objects

$\therefore$ From equation (1) and (2),

$$\frac{1}{9}-\frac{1}{x}=\frac{1}{24-x}-\frac{1}{9}$$

$$\frac{2}{9}=\frac{1}{x}+\frac{1}{24-x}$$

$$\frac{2}{9}=\frac{24-x+x}{x(24-x)}$$

$$x(24-x) = \frac{24\times 9}{2} = 108$$

$x^2 - 24x + 108 = 0$

From Sridharacharya rule,

$$x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

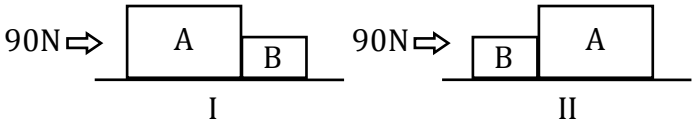
$$x = \frac{24\pm\sqrt{576-4\times1\times108}}{2}$$

$$x = \frac{24\pm\sqrt{144}}{2}$$

$x = 18, 6$

$\therefore$ The correct option is (B).

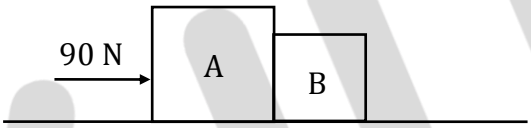
17. Two blocks A and B are in contact with each other and are placed on a frictionless horizontal surface. A force of 90N is applied horizontally on block A (situation I) and the same force is applied horizontally on block B (situation II). Mass of A is 20kg and B is 10kg. Then, the correct statement is



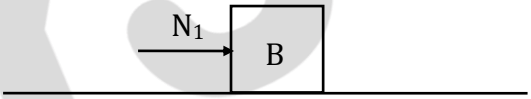
(A) Since both the blocks are in contact, magnitude of force by block A on B will be 90N (situation I) and magnitude of force by block B on A will also be 90N (situation II).
(B) Magnitude force by block A on B is 30N (situation I) and magnitude of force by block B on A is 60N (situation II).
(C) Magnitude of force by block A on B is 60N (situation I) and magnitude of force by block 8 on A is 30N (situation II).
(D) The 90N force will produce acceleration of different magnitudes in A and B.

Sol. **(B)**

Case I



$$\vec{a}_{net} = \frac{\vec{F}_{net}}{m_{total}} = \frac{90N}{30kg} = 3\ m/sec^2$$



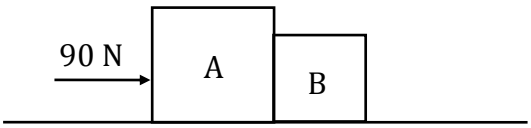
[$N_1$is normal force applied by A on B]

$\Rightarrow \vec{N}_1 = m_B\, a_{net}$

$\Rightarrow \vec{N}_1 = 10\ K\,g \times 3\ m/sec^2$

$\Rightarrow \vec{N}_1 = 30\ N$

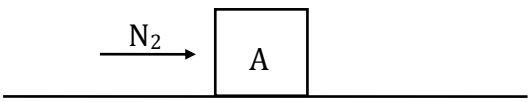
Case II



$$\vec{a}_{net} = \frac{\vec{F}_{net}}{m_{total}} = \frac{90N}{30Kg} = 3\ m/sec^2$$

$\Rightarrow \vec{N}_2 = m_A \vec{a}_{net}$

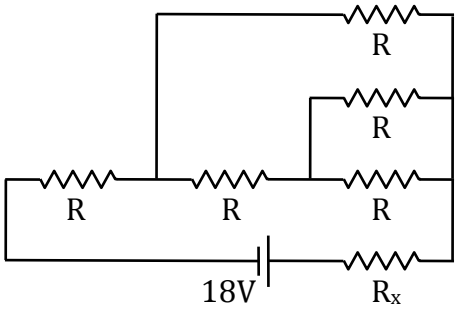
$\Rightarrow \vec{N}_2 = 20\ Kg \times 3\ m/sec^2$



$\Rightarrow \vec{N}_2 = 60\ N$

So, option (B) is correct.

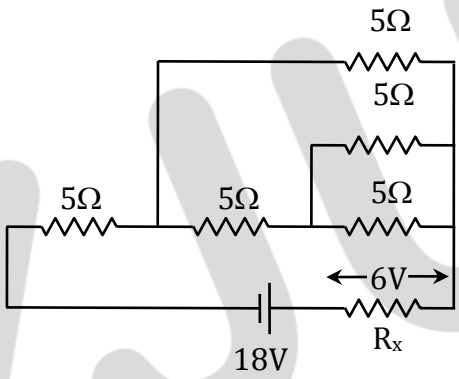
18. In the adjoining circuit, $R = 5\Omega$. It is desired that R_x should be



(A) 4Ω (B) 12Ω (C) 16Ω (D) 20Ω

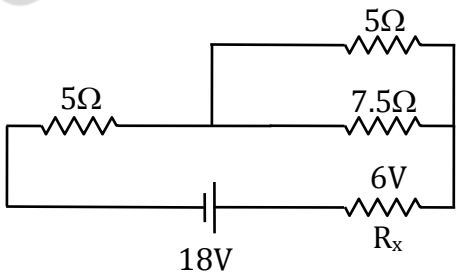
Sol. **(A)**

Now, according to the question;



On reducing the circuit.

⇒



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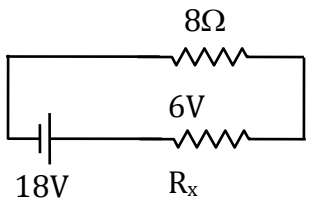


$R_{eq} = 8 + R_x$

Now according to the Ohm's law;

$\because$ V = IR

$\Rightarrow I = \frac{V}{R_{eq}} = \frac{18}{8+R_x}$

Now, $V_x = I \times R_x$

$V_x = \left(\frac{18}{8+R_x}\right) \times R_x$

$6 = \left(\frac{18}{8+R_x}\right) \times R_x$

$\Rightarrow 6(8 + R_x) = 18 \times R_x$

$\Rightarrow 8 + R_x = 3R_x$

$\Rightarrow 8 = 2R_x$

$\Rightarrow R_x = 4\,\Omega$

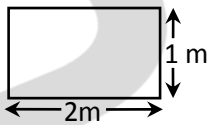
19. In a process of waterproofing, a fabric is exposed to $(CH_3)_2SiCl_2$ vapors. It reacts with the hydroxyl groups on the surface of the fabric or with traces of water to form a waterproofing film $\left[(CH_3)_2SiO\right]_n$, through the following reaction;

$$n(CH_3)_2SiCl_2 + 2nOH^- \rightarrow 2nCl^- + nH_2O + \left[(CH_3)_2SiO\right]_n$$

Where n stands for a larger integer. The waterproofing film is deposited on the fabric layer upon layer. Each layer is 6Å thick [the thickness of the $(CH_3)_2SiO$ group]. How much $(CH_3)_2SiCl_2$, is needed to waterproof one side of a piece of fabric, $1m$ by $2m$, with a film 300 layers thick? The density of the film is 1.0g/cm³.

(A) 0.63g (B) 0.36g (C) 6.3g (D) 3.6g

Sol. **(B)**



1 m × 2 m

$\Rightarrow$ 100 cm × 200 cm

$\Rightarrow$ Area = 2×10^4 cm²

300 layer thick (6A°/layer)

1800 A° = 1800×10^{-10} m = 18×10^{-8} m = 18×10^{-6} m

d = 1 gm / cm³

Volume = 2×10^4 cm² × 10^{-6} cm

$\Rightarrow 36 \times 10^{-2}$ cm²

$\Rightarrow$ 0.36 cm³

$d = \frac{mass}{volume}$

$Mass = \frac{1gm}{cm^3} \times 0.36 cm^3$

Mass = 0.36 gm

20. Given that at a certain temperature, in 1.5L vessel, 5.0mole of A, 7.0mole of B and 0.1 mole of C are present. Then, the value of equilibrium constant for the reaction $A + B \rightleftharpoons 2C + \text{heat}$ is about

(A) 7.22×10^{-5} (B) 2.31×10^{-4} (C) 7.22×10^{-4} (D) 6.11×10^{-4}

Sol. **(B)**

1.5 L

$n_A = 5$ mol

$n_B = 7$ mole

$n_C = 0.1$ mol

$A + B \rightleftharpoons 2C$

$$K_C = \frac{[C]^2}{[A][B]}$$

$$\text{Concentration} = \frac{\text{mole}}{V_{sol.}(L)}$$

$$[C] = \frac{0.1}{1.5}; \quad [A] = \frac{5}{1.5} \quad [B] = \frac{7}{1.5}$$

$$K_C = \frac{\left[\frac{0.1}{1.5}\right]^2}{\left[\frac{5}{1.5}\right]\left[\frac{7}{1.5}\right]} = \frac{10^{-2}}{35} \Rightarrow \frac{100\times10^{-4}}{35}$$

$K_C = 2.86 \times 10^{-4}$

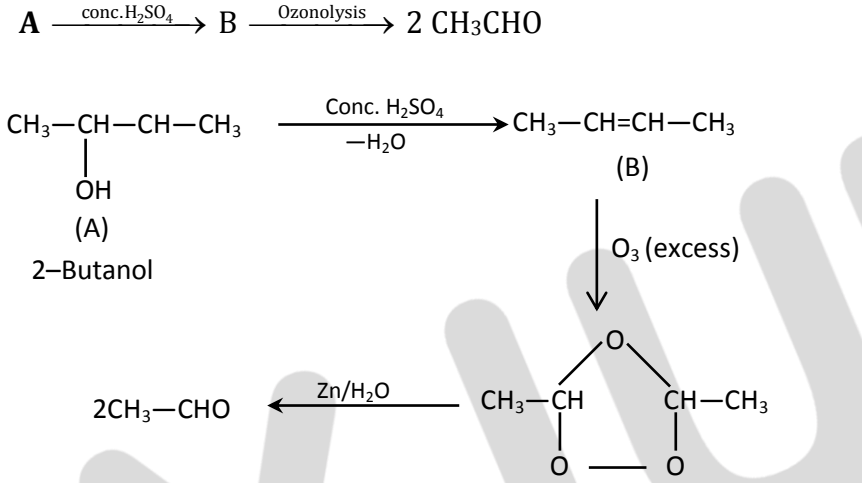
Choose the closest option.

Hence, option (B) is correct i.e., 2.31×10^{-4}.

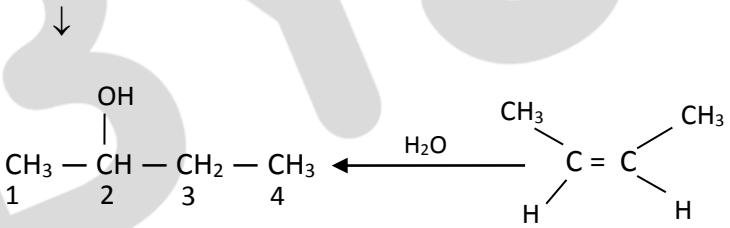
21. An alcohol (A) on dehydration with conc. H_2SO_4 at a high temperature yields compound (B). On ozonolysis, every molecule of compound (B) yields two molecules of acetaldehyde. Which of the following is the starting alcohol (A)?

(A) 1 - butanol (B) 2 - butanol (C) propanal (D) 2 -propanol

Sol. **(B)**



Alternate



Butan – 2 – ol

22. In an experiment with 100 mL 0.1 M solution of Copper Chloride, by mistake 5 gms of a mixture containing equal weights of Tin, Silver, Lead and Calcium, was added. Finally, after some time, the solution gets completely decolorized. This is mainly due to:

(A) Silver reacts with Copper Chloride.

(B) Calcium reacts with Copper Chloride.

(C) All the metals react with Copper Chloride.

(D) Only Lead reacts with Copper Chloride Forming white precipitate of lead chloride.

Sol. **(B)**

Given: $CuCl_2 \longrightarrow$ 100 ml 0.1 M

5g mixture of equal weight of Sn, Ag, Ca and Pb.

Wt of Ca in mixture = $\frac{5}{4}$ = 1.25 g

Moles of Ca = $\frac{1.25}{40}$ = 0.03125 mol

According to the electrochemical series, reactivity order of metals is

Ca > Sn > Pb > Cu > Ag

$\because$ We know that $M = \frac{\text{Moles}}{V(L)}$

$0.1 = \frac{\text{Moles of } CuCl_2}{0.1(L)}$

Moles of $CuCl_2$ = 0.01 mol

$\because$ Here, Ca has the highest reactivity. So, it reacts firstly with $CuCl_2$ and forms $CaCl_2$ compound as follows –

Ca	+	$CuCl_2$	$\longrightarrow$	$CaCl_2$	+	Cu
0.03125		0.01 (limiting reagent)		(water soluble)		
0.02125		0		0.01		

Hence, due to the formation of $CaCl_2$ colour of solution decolorized.

23. Suppose that A and B forms compound B_2A_3 and B_2A. If 0.05 mole of B_2A_3 weighs 12 g and 0.1 mole of B_2A weighs 10 g, what are the atomic weight of A and B respectively?

(A) 70 and 25 (B) 50 and 20 (C) 40 and 30 (D) 30 and 40

Sol. **Bonus**

Given: $(\text{Mole})_{B_2A_3}$ = 0.05 Mol

= $(\text{Weight})_{B_2A_3}$ = 12 g

$(\text{Mole})_{B_2A}$ = 0.1 Mol

$(\text{Weight})_{B_2A}$ = 10 g

We know, mole = $\frac{\text{weight}}{\text{molecular weight}}$

Molecular weight = $\frac{\text{weight}}{\text{mole}}$

$(\text{m.wt.})_{B_2A_3} = \frac{12}{0.05} = 240$

$2B + 3A = 240$ ...(i)

$(\text{m.wt.})_{B_2A} = \frac{10}{0.1} = 100$

$2B + A = 100$ ...(ii)

Subtracting equation (ii) from equation (i),

$2B + 3A = 240$

$2B + A = 100$

$- \quad - \quad -$

$2A = 140 \Rightarrow A = 70$

and $B = 15$

24. Triclosan ($C_{12}H_7Cl_3O_2$) is an antibacterial and antifungal agent. It is a polychlorophenoxy phenol. It is widely used as a preservative and antimicrobial agent in personal care product such as soaps, skin crasms, and deodorants etc. A label on a 200 mL hand sanitizer bottle claims that it contains Triclosan 0.2% w/v. What will be the number of molecules of Triclosan present in the bottle? (N_A is Avogadro's Number)

(A) $1.4 \times 10^{25}\ N_A$ (B) $1.4 \times 10^{24}\ N_A$ (C) $1.4 \times 10^{23}\ N_A$ (D) $1.4 \times 10^{22}\ N_A$

Sol. **Bonus**

Given:

200 mL $\longrightarrow$ 0.2 % w/V

In 100 mL weight of triclosan = 0.2 g

So, in 200 mL $\longrightarrow$ 0.4g

Weight of Triclosan ($C_{12}H_7Cl_3O_2$) = 0.4 g

Mole = $\frac{\text{Weight}}{\text{Molecular weight}} = \frac{0.4}{289.5}$

Mole = $0.001382 = 0.0014 = 1.4 \times 10^{-3}$

Mole = $\frac{\text{Number of molecules}}{N_A}$

No. of molecules = $1.4 \times 10^{-3} \times N_A$

PART-A-2

25. If $0 \le x \le \pi$ and $81^{\sin^2 x} + 81^{\cos^2 x} = 30$, then x =

(A) $\frac{\pi}{6}$ (B) $\frac{\pi}{3}$ (C) $\frac{5\pi}{6}$ (D) $\frac{2\pi}{3}$

(Useful information: $\pi^C = 180°$, $\sin(180 - \theta) = \sin\theta$, $\sin\theta \ge 0$ when $0 \le \theta \le 180°$]

Sol. **(ABCD)**

$81^{\sin^2 x} + 81^{(1-\sin^2 x)} = 30$

$81^{\sin^2 x} + \frac{81}{81^{\sin^2 x}} = 30$ {Let $81^{\sin^2 x} = t$

$t + \frac{81}{t} = 30$

$t^2 + 81 = 30t.$

$t^2 - 30t + 81 = 0$

$(t - 3)(t - 27) = 0$

$t = 3, t = 27$

$81^{\sin^2 x} = 3$ or $81^{\sin^2 x} = 27$ (By comparing powers)

$\sin^2 x = \frac{1}{4}$ or $\sin^2 x = \frac{3}{4}$

$\sin x = = \frac{1}{2}, \sin x = \frac{\sqrt{3}}{2}$

$\sin x = \frac{\pi}{6}$ or $\sin x = \frac{\pi}{3}$

or $x = \pi - \frac{\pi}{6} = \frac{5\pi}{6}$ or $\sin x = \pi - \frac{\pi}{3} = \frac{2\pi}{3}$

So, $x = \frac{\pi}{6}, \frac{\pi}{3}, \frac{5\pi}{6}$ and $\frac{2\pi}{3}$

26. Given $(a-b)^2 + (a-c)^2 = (b-c)^2$, then which of the following statements are true?

(A) Equation is valid when b = c and $a \neq c$

(B) Equation is valid when a = b

(C) Equation is valid when a = c

(D) Given equation is not valid when a, b and c are distinct.

Sol. **(BCD)**

$(a-b)^2 + (a-c)^2 = (b-c)^2$

(A) $b = c, a \neq c$

$(a-c)^2 + (a-c)^2 = 0$

$2(a-c) = 0$

a = c (Not Follow)

(B) a = b

$(a-a)^2 + (a-c)^2 = (a-c)^2$

a = c

(C) a = c

$(a-b)^2 + (a-a)^2 = (b-a)^2$

$(a-b)^2 = (b-a)^2$

a – b = b – a

2a = 2b

a = b

(D) We can say from option (B) and (C) that option (D) is also correct.

27. Choose the correct statement from the following options.

(A) A robust adaptive immune response is initiated using weakened form of the bacterium know as live attenuated vaccines.

(B) Administration of a killed or chemically inactivated virus can trigger a weaker adaptive immune response, but can be strengthened with booster doses.

(C) A conjugate or multivalent component always reduces immunogenicity of the vaccine.

(D) Inclusion of alum, cytokines, and / or lipids always reduces the immune response to a vaccine.

Sol. **(AB)**

Live vaccines use a weakened (or attenuated) form of the germ that causes a disease. Because these vaccines are so similar to the natural infection that they help prevent, they create a strong and long-lasting immune response. Just 1 or 2 doses of most live vaccines can give you a lifetime of protection against a germ and the disease it causes. Live vaccines are used to protect against: Measles, mumps, rubella (MMR combined vaccine) **;** Rotavirus; Smallpox; Chickenpox; Yellow fever

That makes option (a) the correct statement.

Option (b) –correct

A killed or chemically inactivated vaccines use the killed version of the germ that causes a disease. Inactivated vaccines usually don't provide immunity (protection) that's as strong as live vaccines. So, you may need several doses over time (booster shots) in order to get ongoing immunity against diseases. Inactivated vaccines are used to protect against; Hepatitis A; Flu (shot only); Polio (shot only); Rabies. So, the statement given in option b is correct.

Option (c) – Incorrect

A conjugate or multivalent vaccines use specific pieces of the germ (conjugate)— like its protein, sugar, or capsid (a casing around the germ). Because these vaccines use only specific pieces of the germ, they give a very strong immune response, i.e. a high immunogenicity, that's targeted to key parts of the germ.

Such vaccines are used to protect against; Hib (*Haemophilus influenzae* type b) disease; Hepatitis B; HPV (Human papilloma virus); Whooping cough (part of the DTaP combined vaccine); Pneumococcal disease; Meningococcal disease; Shingles.

So, a multivalent component is added to achieve a strong immune system response; because it increases the immunogenicity of vaccine. Making option-C incorrect statement.

Option – (d) =incorrect

Inclusion of Alum, cytokines or lipid does not always reduces the immune response to a vaccine. In fact alum (phitakiree) is an adjuvant (a preparation that enhances the immunogenicity of an antigen) most often used in vaccines in humans.

Cytokines regulate adaptive immunity and are produced primarily by T-lymphocytes that have recognized an antigen (Hereby antigen introduced via vaccine), specific for that cell. These cytokines function in the proliferation and differentiation of B-lymphocytes and T-lymphocytes after antigen recognition and in the activation of effector cells.

Lipid metabolism and the immune system are intertwined. Lipid-induced immune responses that take place in peripheral tissues often lead to chronic cardio-metabolic diseases.

Hence, all of them has an effect on immune response to a vaccine (weakened/ attenuated or killed version of the germ/ antigen that causes a disease), it may be enhanced or suppressed but not always reduce it that makes statement of option D incorrect.

28. The minimum energy required to exist that is the energy required to perform chemical reactions even when a person is at rest is called the basal metabolic rate (BMR), which accounts for about 50 to 70% of the daily energy expenditure in most sedentary individuals. It is influenced by many factors. Some statements are made about these factors. Choose the correct statements from the following options.

(A) The Thyroid hormone decreases the metabolic rate.

(B) The growth hormone increases the metabolic rate.

(C) Fever decreases the metabolic rate.

(D) Malnutrition decreases the metabolic rate.

Sol. **(BD)**

Option (b)- correct.

Pituitary growth hormone (GH) is a peptide hormone predominantly secreted by the anterior pituitary. GH plays critical roles in regulating somatic growth and the metabolism of carbohydrates, lipids, and protein. GH effects metabolism by suppressing glucose uptake and glucose oxidation, and stimulates gluconeogenesis, glycogenesis, and lipolysis. GH antagonises the action of insulin on peripheral tissues and thereby decreases glucose uptake and increases glucose production and thereby increases the metabolic rate; making option (B) the correct statement.

Option (d) –correct

Prolonged periods of abnormal nutrition cause an adaptive change in BMR. In prolonged malnutrition, the BMR declines, while in prolonged overnutrition, the BMR is increased. So, the statement (D) is correct that malnutrition decreases the metabolic rates.

Option (a)- Incorrect

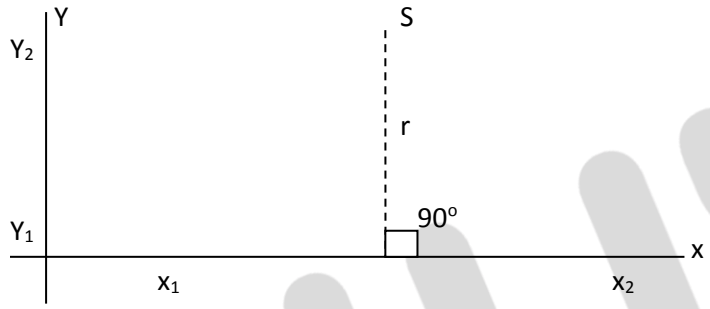
Thyroid hormones has a marked effect on BMR, since thyroid hormones regulate the rate of cellular metabolism. Hyperthyroidism—in which there is an increase in the production of thyroid hormones—leads to a high BMR, while hypothyroidism—in which thyroid hormones are depleted—causes a low BMR.

So, thyroid hormone has both (increase/decrease) effects over BMR; not only a decrement effect; making option A an incorrect statement.

Option (c) –incorrect

Fever is a common pathological cause for a high BMR, since a rise in body temperature increases the rate of cellular metabolic reactions. It is estimated that for every degree Fahrenheit of rise in body temperature, the BMR increases by 7 percent, that makes option C incorrect statement.

29. An infinitely long conductor when carrying current/ produces a magnetic field B around it, if such a conductor is placed along the X-axis, then the magnitude of B at a distance r is given by the relation $B = \frac{\mu_o}{4\pi}\frac{2I}{r}$, (where $\frac{\mu_o}{4\pi} = 10^{-7} NA^{-2}$ is a constant). The Following figure shows such an infinitely long conductor placed along X-axis carrying current / and B at S is 2×10^{-4} T, directed into the plane of the paper at S. Given r = 1 cm. Then, the correct statements are:



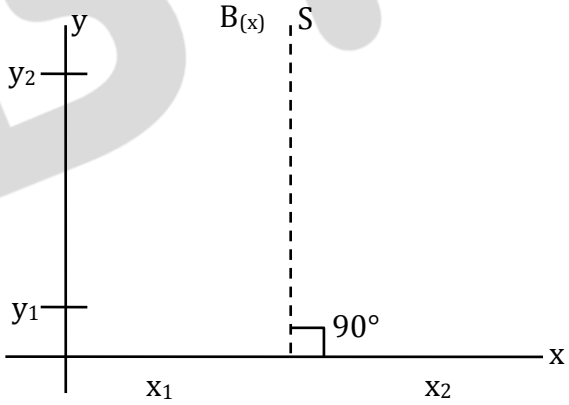
(A) I = 10 A

(B) The number of electrons transported across the cross section of the conductor during time 1s is 6.25×10^{19}

(C) The direction of current is from x_2 to x_1

(D) The electrons will flow in the direction x_2 to x_1

Sol. **(ABC)**



Given that magnitude of a magnetic field $B = \frac{\mu_0}{4\pi}\frac{2I}{r}$ ...(1)

$\frac{\mu_0}{4\pi} = 10^{-7}\ NA^{-2}$ ...(2)

Current = I

$B = 2 \times 10^{-4}$ T ...(3)

$r = 1\ cm = 1 \times 10^{-2}$ m. ...(4)

Substituting the values from equations (2), (3) and (4) in equation (1), we get

$2 \times 10^{-4} = 10^{-7} \times \frac{2I}{10^{-2}}$

$\Rightarrow$ I = 10 A

$\therefore$ Option (A) is correct.

As from the definition of current (I) = $\frac{\text{Charge}(q)}{\text{time}(t)}$

$\Rightarrow$ q = I × t = 10 × 1 = 10 C

$\because$ q = ne $\Rightarrow$ n = $\frac{q}{e}$

The number of electrons n = $\frac{10}{1.6\times10^{-19}} = 6.25 \times 10^{19}$

Option (B) is correct.

From right hand thumb rule as magnetic field is directed into the plane of paper, therefore thumb represents the direction of current i.e., from x_2 to x_1.

$\therefore$ Option (C) is correct.

$\because$ Electrons flow opposite to the direction of current, therefore the direction of electrons flow will be from x_1 to x_2.

$\therefore$ Option (D) is incorrect.

Option (A, B, C) are correct.

30. The ratio of the charge of an ion or subatomic particle to its mass (q/m) is called specific charge. Then, the correct options are

(A) Si unit of specific charge can be written as A-S / kg.

(B) If all the isotopes of hydrogen are ionized then tritium will have least specific charge among them.

(C) Specific charge of an α-particle will be greater than that of an electron.

(D) Specific charge ratio of an electron is 1.75×10^{11} / kg.

Sol. **(ABD)**

Specific charge (S.C.) = $\frac{C \leftarrow \text{Column}}{m \leftarrow \text{Kg}}$

(A) S.I. unit $\Rightarrow$ C/Kg $\Rightarrow \frac{\text{Amp.sec}}{\text{Kg}}$ (Correct)

(B) Ionized isotopes : $(_1H^1)^+$, $(_1H^2)^+$, $(_1H^3)^+$,

S.C. $\propto \frac{1}{\text{mass}}$ (Here, the charge is same)

Mass of $_1H^3$ is maximum S.C. of $_1H^3$ is minimum (Correct)

(C) Incorrect

(D) Correct

31. Acetylene torches and burner used by glassblowers produce intense ultraviolet light. Glassblowers wear special glasses that contain which of the following elements to absorb the UV?

(A) Neodymium (B) Praseodymium (C) Cerium (D) Didymium

Sol. **(D)**

At almost 1600°C, our furnances and these torches gives off harmful UV rays that could permanently damage any part of the human eye.

Didymium works by filtering yellowish light that is closely related to UV rays.

This is because didymium does not absorb all visible light.

32. Equal lengths of magnesium ribbons are taken in four test tubes A, B, C and D. In test tube A, 1M acetic acid is added; in test tube B, 1M HCl is added; in test tube C, 1M HNO_3 is added; and in test tube D, 1M NaOH is added. The observed results will be:

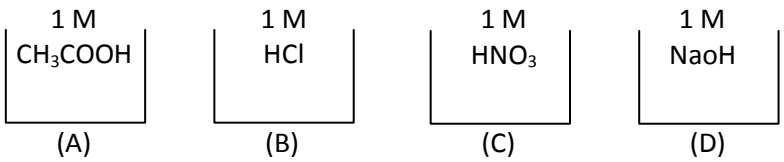
(A) The fizzing occurs more vigorously in A.

(B) The fizzing occurs more vigorously in B.

(C) The fizzing occurs more vigorously in C.

(D) The fizzing occurs more vigorously in D.

Sol. **(BC)**



Both HCl and HNO_3 are strong acids. So, they vigorously react with Mg ribbon and produce $H_2(\uparrow)$. Hence, options (B) and (C) are correct.

IOQJS-2021_Code-55

Number of Questions: 21 **Time: 2 Hours** **Max Marks: 120**

INSTRUCTIONS

Section-I	Q.1 to Q.12	(SCQ)
Section-II	Q.13 to Q.21	(Subjective)

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

Sol. **(C)**

Humans protect themselves whenever they sense a threat. Their basic impulse to protect themselves is automatic and unconscious. Amygdala (a part of limbic system; plays an important role in emotion and behaviour) is responsible for detecting fear and preparing our body for an emergency response. It sounds an alarm by sending signals to the hypothalamus, which stimulates the autonomic nervous system (ANS) and releases stress hormones adrenaline and cortisol in blood. These hormones immediately prepare us for fight or flight and allow the mind to be as open as possible.

Some immediate changes occur and these sensations are not exactly pleasant as they are not meant for relaxation. They are designed to move us to action.

Some of these changes are: -

1. Salivation– Increased total protein concentration after short-term acute stress changes the chemical properties of saliva, such as the adhesion or lubrication of oral surfaces and salivary production can be decreased

2. Digestion – Activity in the digestive system also decreases because food is not as important as fighting off danger or fleeing to safety. The energy needed to digest food is therefore used for more immediate survival purposes like providing glucose to brain.

3. Loss of bowel and bladder control – Urination occur when our bladders become full. Brain can stimulate the desire to pee by sending an inhibitory signal to the brainstem (control bladder). When we become stressed or anxious, electrical signals from the limbic system (signals of fear) become so intense that the brainstem has trouble following the brain's commands to hold urine. That's why many people urinate more frequently during stress so body loses bladder control.

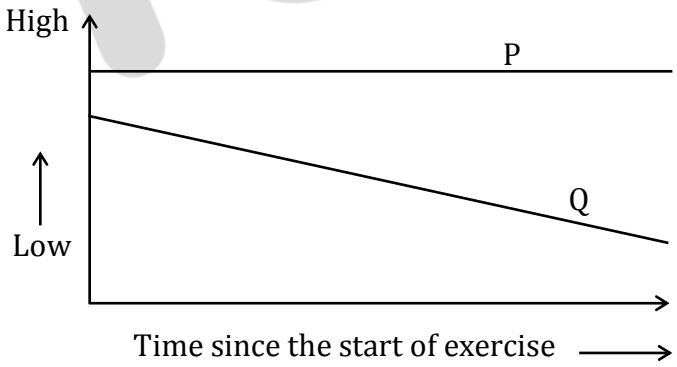
1. Body shivering- Strong emotions can cause a person to shake or shiver. Nerve impulses are sent by the hypothalamus to the skeletal muscles to bring about rapid contractions that generate heat.

2. Crying – Crying is a response to the stress experienced by the sympathetic nervous system.

3. Pupil dilation- In emergency situation, the brain wants complete information of surrounding to get out of the situation so pupils open up, or dilate, to let in more light.

By reading the above lines, iii, iv and vi statements are correct.

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:

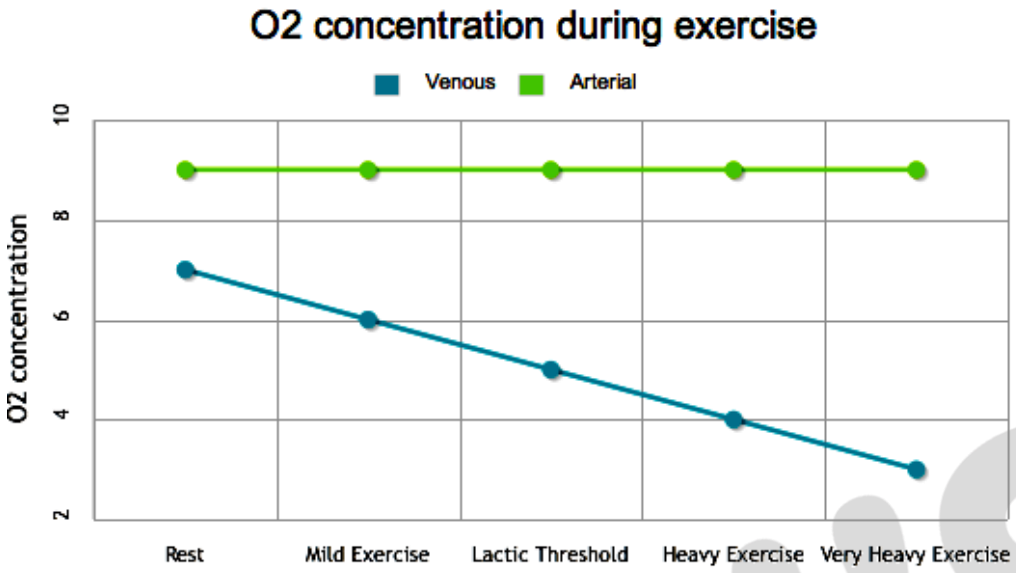
(A) P: carbon dioxide level in vein Q: oxygen level in artery.

(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.

Sol. **(D)**



'P' is oxygen level in artery – Oxygen saturation in blood is .96–98% regardless, breathing is fast or slow or shallow. Out atmosphere has 21% of oxygen but we breath only 5% of it. The cell only use $\frac{1}{4}$th of oxygen we breath. That means we use only 1.25% of the oxygen available in air we breadth. Even in the feeling of breathlessness there is more than enough oxygen.

'Q' oxygen level in vein – Oxygen used in respiration in body tissue.

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 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

Sol. **(C)**

1 bacteria – At 1000x magnification we will be able to see 0.180mm, or 180 microns. Bacteria are too small to see without the aid of a microscope. While some eukaryotes, such as protozoa, algae and yeast, can be seen at magnifications of 200X-400X, most bacteria can only be seen with 1000X magnification.

Bacteria cells have ribosomes and a cell wall, but they don't have organelles such as nuclei, mitochondria or chloroplasts. Bacteria cells do have a cytoplasm and cell membrane. One of the key structures of a bacteria cell is the plasmid.

2 plant cell – Using a light microscope of 100x magnification power, we can view cell walls, vacuoles, cytoplasm, chloroplasts, nucleus and cell membrane of plant cell.

Plant cells have a cytoplasm, cell membrane, mitochondria and nucleus which all perform the same functions as animal cells. Mitochondria are needed to release energy from sugar, plant cells need this energy to function just as animal cells.

3 ribosome - A ribosome is a cell organelle which can be seen only through electron microscope and cannot be seen with a light microscope. It functions as a micro-machine for making proteins. Ribosomes are found 'free' in the cytoplasm or bound to the endoplasmic reticulum (ER) to form rough ER.

When viewed through an electron microscope, free ribosomes appear as either clusters or single tiny dots floating freely in the cytoplasm. Ribosomes may be attached to either the cytoplasmic side of the plasma membrane or the cytoplasmic side of the rough endoplasmic reticulum.

4 virus – Viruses are very small and most of them can be seen only by TEM (transmission electron microscopy). TEM has therefore made a major contribution to virology, including the discovery of many viruses, the diagnosis of various viral infections and fundamental investigations of virus–host cell interactions.

A virus is a small collection of genetic code, either DNA or RNA, surrounded by a protein coat. A virus cannot replicate alone. Viruses must infect cells and use components of the host cell to make copies of themselves. Often, they kill the host cell in the process, and cause damage to the host organism.

By reading above lines statement (C) is correct.

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.

Sol. **(C)**

Solid wastes are discarded solid materials which are produced due to various human activities.

(1) Kitchen waste- Vegetables and fruit peelings are the number one food remnants of kitchen containing some living tissues of plants and nutrients of plants and animals.

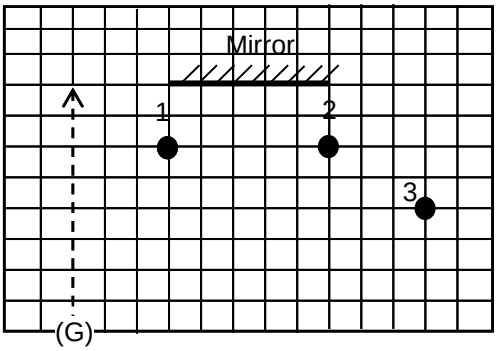
(2) Cut pieces of old papers- Paper is a valuable material for composting because it's a great source of carbon. The carbon black adheres to the paper with the help of various waxes. Paper is made mostly out of organic compounds: that is carbon, hydrogen and oxygen (C, H and O).

(3) Spoonful of sour buttermilk - Buttermilk consists mostly of water, the milk sugar lactose, and the milk protein casein and lactic-acid-producing bacteria LAB (Lactococcus lactis). When Lactococcus lactis is added to milk, the bacterium uses enzymes to produce energy (ATP) from lactose. The by-product of ATP production is lactic acid. The lactic acid curdles the milk that then separates to form curd. Hence, acidity of the milk increases but not of the buttermilk.

(4) Soil- Soil is a major source of nutrients needed by plants for growth. The three main nutrients are nitrogen (N), phosphorus (P) and potassium (K). Together they make up the trio known as NPK.

By reading the above lines we can say that statement (C) is correct.

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.

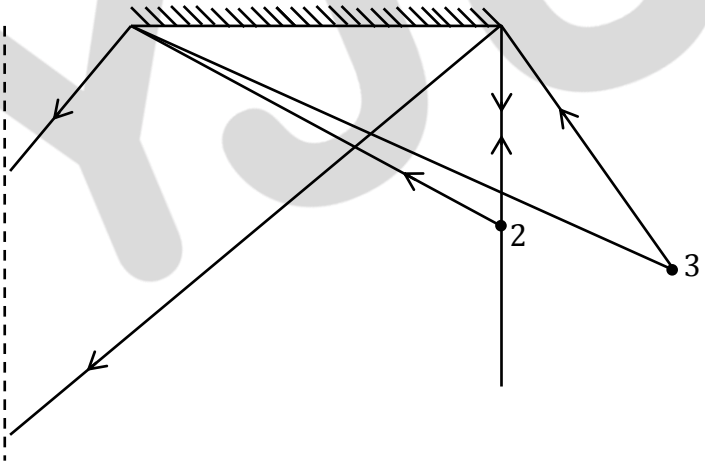


The order in which she will see images of the toys is:

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

Sol. **(D)**

Image of 1st toy, will never be visible to the girl. According to the concept of field of view, it is clear that image of the 2nd toy will appear earlier than the 3rd toy.



So, option (D) is correct

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

Sol. **(A)**

According to the Ohm's law;

$V=IR$

$220 = 5(R)$

$R = 44\ \Omega$

It is given that the wire can bear a maximum current of 5A. So, the resistance of equal pieces of wire can't be less than $44\ \Omega$

(for maximum power output, all pieces should be connected in parallel)

$\Rightarrow \frac{310}{7} = 44.28\Omega$

So, according to the options, 7 equal pieces should be made.

So, option (A) is correct.

7. Consider the following two statements:

Statement S1: If you put 100g ice at 0°C and 100g 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.

Sol. **(D)**

$\text{Water}(\ell) \xrightarrow{0°C} \text{ice(s)} + Q_1 \xrightarrow{-10°C} \text{ice} + Q_2$

Total heat loss by water to form ice at –10°C

$Q_{water} = Q_2 + Q_1$

$Q_{water} = mS\Delta T + mL$

Where, S = specific heat of ice = $\frac{1}{2}$ Cal/gm°C

L = latent heat of ice = 80 Cal/gm

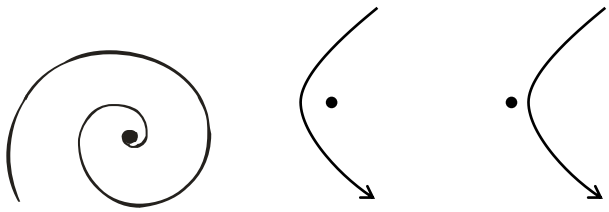
m = mass

$Q_{water} = 100 \times \frac{1}{2} \times 10 + 100 \times 80 = 8500$ Cal

$Q_{ice} = mS\Delta T = 100 \times \frac{1}{2} \times 10 = 500$ Cal

At 0°C, ice is less dense than water because the orientation of hydrogen bonds causes molecules to push further apart, which lowers the density of ice.

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



I II III

The correct statement about the trajectories is:

(A) I represents trajectory for Halley's Comet and II for the scattering of aloha 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.

Sol. **(D)**

The path of comet will be elliptical. So, its followed trajectory will be II according to the figure. The α-particle will also be repelled by the nucleus, since both are of same nature (positive). So, it's trajectory will be III according to the figure.

So, option (D) is correct.

9. When water changes phase from liquid to vapour, 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.

Sol. **(B)**

Liquid water contains H-bond, when we heat the water (i.e. change it from liquid to vapour), H-bonds break between H_2O molecules and it get vaporized as $H_2O(g)$.

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.

Sol. **(B)**

Diffusion will be time consuming and cannot be completed almost instantaneously because dissolution of crystals will take time.

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.

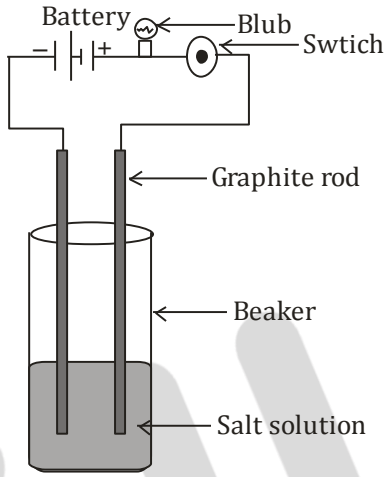
(C) removal of dissolved carbon dioxide from the water.

(D) reaction of cationic species in the water with atmospheric oxygen.

Sol. **(C)**

Rain water contains oxides of carbon, sulphur like CO_2 and SO_2 dissolved in it. On boiling, these gases escape out. So, electric conductivity of water gets lowered after boiling.

12. Consider a setup in which two graphite rods are immersed in a 2M NaCl(aq.) solutions. The rods are connected to two terminals of a 9V 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.

Sol. **(C)**

Due to the flow of electrons, current is generated so that the bulb will glow.

Cathode – $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Anode – $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Overall reaction – $2H_2O + 2Cl^-(aq) \rightarrow H_2 + Cl_2 + 2OH^-(aq)$

$Na^+ + OH^- \rightarrow NaOH$, pH > 7

At room temperature, graphite electrode cannot be oxidized by O_2.

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 ions as AgCl(s), and finds the mass of the AgCl precipitate to be 5.32g. Calculate the mass percentage of $MgCl_2$ in the original mixture. (Atomic masses should be taken as per the data given.)

Sol. **61%**

Weight of $MgCl_2$ and KNO_3 mixture = 2.89g

Weight of precipitate AgCl = 5.32 g

Molecular weight of AgCl = 143.5g

Moles of AgCl = $\frac{5.32}{143.5} = 0.0371$

Reaction of $MgCl_2$ with $AgNO_3$ follow as

$$\underset{x}{MgCl_2} + 2AgNO_3 \rightarrow \underset{2x}{2AgCl} + Mg(NO_3)_2$$

From the above equation

Moles of $MgCl_2 = \frac{\text{Moles of AgCl}}{2} = \frac{0.0371}{2} = 0.1855$

$\therefore$ weight of $MgCl_2$ = moles × molecular weight

= 0.1855 × 95 = 1.762 g

$\therefore$ % of $MgCl_2$ in mixture = $\frac{1.762}{2.89} \times 100 = 60.97\% = 61\%$

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 $5cm^3$ distilled water. A drop of this solution is put on a moist pH paper.

ii. 0.5 gram KI is dissolved in about $5cm^3$ 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 $5cm^3$ 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.

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 500mL alcohol and then adding distilled water to make the volume 100mL. 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.

Solution (14.1 to 14.3):

14.1. (a) $KI \xrightarrow{H_2O}$ KOH + HI

Strong Base — Strong Acid

Hence, pH of the solution = 7

and colour of the pH paper will be green.

(b) Since KI is expensive, on preparing the solution, test III can be performed initially followed by test I and then test II, so minimum amount of KI per student = 0.5 g.

Total number of students = 36

$\therefore$ Total amount of KI = 36 × 0.5 = 18g

14.2. (a) $KI + H_2O_2 + H_2SO_4 \rightarrow I_2 + K_2SO_4 + 2H_2O$

(b) $\overset{-1}{K}\overset{-1}{I} + H_2\overset{-1}{O_2} + H_2SO_4 \longrightarrow \overset{0}{I_2} + K_2SO_4 + 2H_2\overset{-2}{O}$

Reduction (oxidizing agent)

oxidation (reducing agent)

Hence, KI is a reducing agent.

(c) Filtration

14.3. (a) $2KI \xrightarrow{\Delta} 2K(s) + I_2\uparrow$

(Violet colour)

(b) Potassium remains in test tube

Symbol $\rightarrow$ K(s)

(c) $\because$ Here, first we heat than liberation of I_2 occurs.

Hence, it is an thermal decomposition reaction.

14.4. Reaction of KI with I_2 follow as

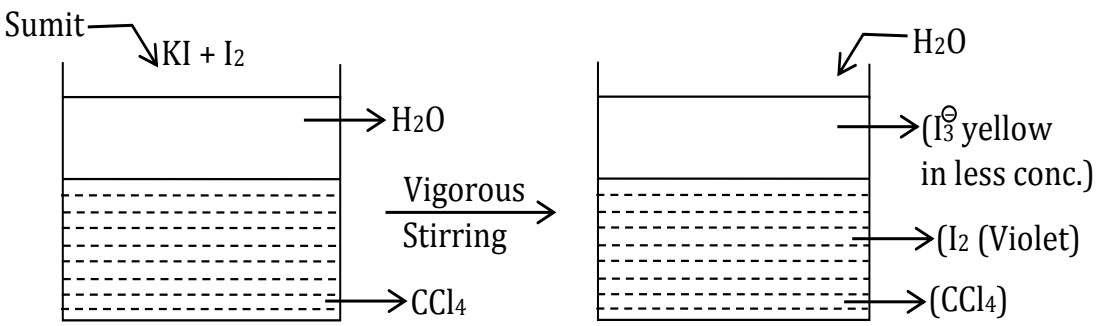
$KI + I_2 \rightarrow I_3^{\ominus} + K^+$ ($I_2 \rightarrow$ Non-polar)

$\because$ Here, $I_3^{\ominus}$ & K^+ are ionic or polar in nature.

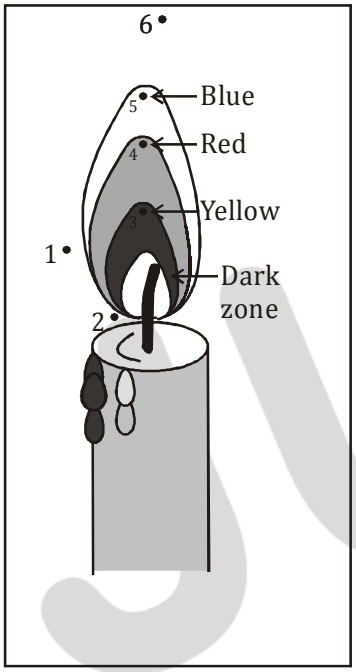
So, KI dissolved only in water.

$\Rightarrow$ After addition of CCl_4, two layers are formed due to density difference.

But when we are vigorously stirring the solution, I_2 (non-polar) gets dissolved in CCl_4 (non-polar) and $I_3^{\ominus}$ (polar) in H_2O (polar) due to this we get two layers of different colour as follows -



15. 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. Point 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. I. 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 process 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 1.0g 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 the reason for your answer, along with the necessary supporting calculations/arguments.

Solution (15.1 to 15.4)

15.1. (a) The hottest point–5, because of the complete combustion in outermost layer.

(b) The coldest point-2 because of no combustion in dark zone.

(c) At point-6

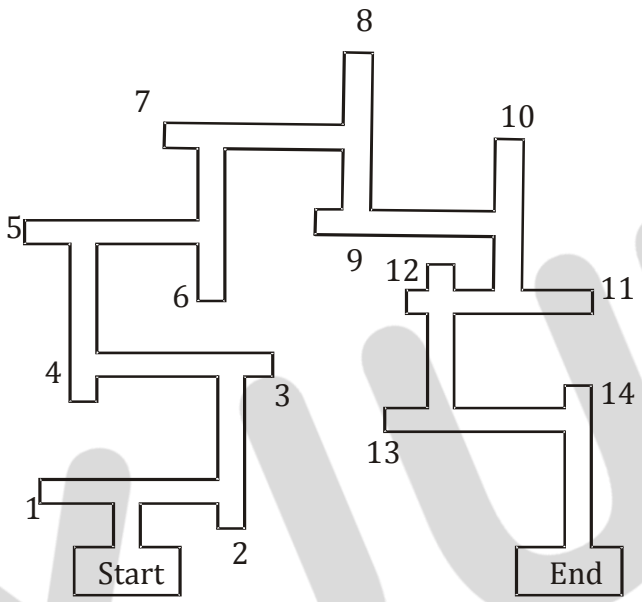
15.2. Carbon and carbon monoxide

15.3. (D)

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

15.4. Naphthalene ($C_{10}H_8$) will give more yellow light because it is unsaturated hydrocarbon and due to the presence of more percentage of carbon, it will produce sooty yellow coloured flame.

16. (8 marks) A famous experiment performed by Tolman and Honzik (in 1930) in which they studied the behaviour of rats in a complex maze for a period of 17 days as shown in the figure. 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.



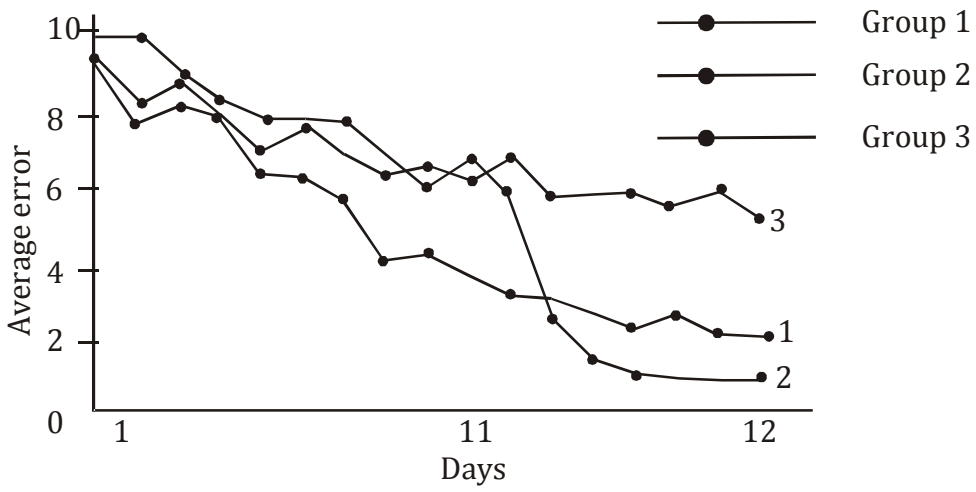
Group I: Day 1–17: Every time the rats reached the end, they were given additional food

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) behaviour 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 an 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 I were kept hungry before the experiment? Assume that all other conditions in the above experiment 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.

Solution (16 to 16.2) :

16 **Simplified version of given scenario**: In this question, the whole experiment is about Latent learning. It is a type of learning which is not apparent in the learner's behaviour at the time of learning, but which manifests later when a suitable motivation and circumstances appear. This shows that learning can occur without any reinforcement of a behaviour.

The idea of latent learning was developed by Tolman; that humans engage in this type of learning everyday as we drive or walk the same route daily and learn the locations of various buildings and objects. Only when we need to find a building or object does learning become obvious. Tolman conducted experiments with rats and mazes to examine the role that reinforcement help rats learn their way through complex mazes. These experiments eventually led to the theory of latent learning.

In their study, 3 groups of rats (healthy and fed regularly) had to find their way around a complex maze. At the end of the maze there was a food box. Some groups of rats got to eat the food, some did not, and for some rats the food was only available after 10 days.

Group 1: Rewarded

Day 1 – 17: Every time they got to end, they were given food (i.e. reinforced).

Group 2: Delayed Reward

Day 1 - 10: Every time they got to end, they were taken out.

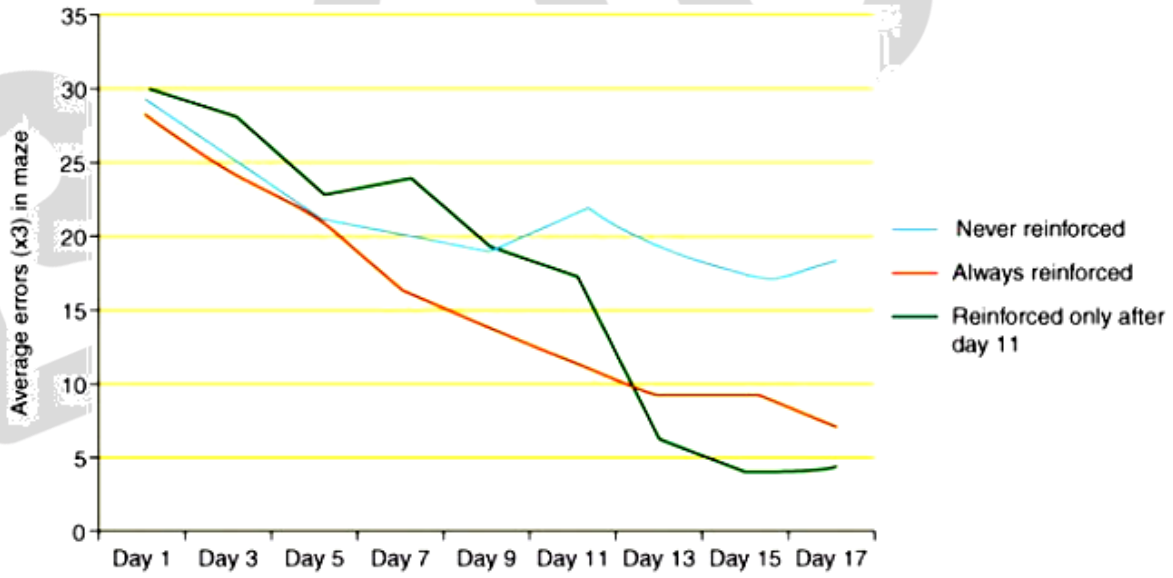
Day 11 -17: Every time they got to end, they were given food (i.e. reinforced).

Group 3: No reward

Day 1 – 17: Every time they got to end, they were taken out.

Following is the simplified version of the graph given in the question

Spatial Learning in Rats Tolamn & Honzik, 1930



For the delayed reward group (Group 2) :

According to the observations made in this experiment, group 2 rats learned the route on days 1 to 10 and formed a cognitive map of the maze. They took longer to reach the end of the maze because there was no motivation/ circumstance for them to perform. From the day 11 onwards, they had a motivation to perform (i.e. food) and reached the end before the reward group.

Case 1 : When the food reward was not introduced in the maze, the error scores and time scores of the rewarded rats showed a large increase.

Case 2 : When reward was introduced into the maze, the non-rewarded rats showed a large decrease in time and error scores.

The drop in the error curve for the group of rats that were rewarded on the eleventh day brought the curve significantly below the curve of a control group of rats that had been rewarded from the first. This shows that between stimulus (the maze) and response (reaching the end of the maze) a mediational process was occurring; the rats were actively processing information in their brains mentally by using their cognitive map (which they had latently learned).

So, with this knowledge now let us start solving asked questions.

16.1 **Statement (a)- TRUE :** From the perspective of neuropsychology, adequate nutrition is essential for healthy brain functioning and optimal learning. The consumption of healthy foods is closely related to adequate brain function and which is a prerequisite for efficient cognition and the performance of organized behaviour. Hence, statement (a) is TRUE that rats need good nutritional status to perform well in the maze.

Statement (b)- FALSE : This statement is false because the stimulus –response behaviour is never genetical. It is a learnt behaviour and hence, changeable also. This is proved by the drop in the error curve for the group of rats that were rewarded on the eleventh day brought the curve significantly below the curve of a control group of rats that had been rewarded from the first. This shows that between stimulus (the maze) and response (reaching the end of the maze) a mediational process was occurring; the rats were actively processing information in their brains by using their cognitive map (which they had latently learned).

Statement (c)- FALSE : This statement which states that the find of the end of maze is by trial and error method and not by learning is wrong. If we talk about group-2; The rats learned the route on days 1 to 10 and formed a cognitive map of the maze. They took longer to reach the end of the maze because there was no motivation/ circumstance for them to perform earlier. From day 11 onwards they had a motivation to perform (i.e. food) and reached the end before the reward group (group-1). It means they learned it , not merely an trial and error method.

Statement (d)- TRUE : Yes, rewarding the rats has improved the end results. This can be seen by comparing the performances of Group 2 with Group 3. Group-2 rats,from day 11 onwards had a motivation to perform (i.e. food) and reached the end before the reward group (group-1). While group 3 performance improved only slightly as getting out of the maze was just a smaller reward.

Statement (e)- TRUE : Yes, there was an active learning in the Group-2 rats even before day 11. They learned the route on days 1 to 10 and formed a cognitive map of the maze. Although they took longer to reach the end of the maze because there was no motivation for them to perform. But from day 11 onwards, they had a motivation to perform (i.e. food) and hence reached the end of the maze even before the group 1.

16.2 (C)

It is well known that the consumption of healthy foods and particular nutrients is closely related to adequate brain functions; a prerequisite for efficient cognition and the performance of organized behaviour. Keeping in mind the importance of healthy diet to achieve a cognitively organized behaviour, and also the importance of the reward in a learning process ; here option C is the most appropriate answer.

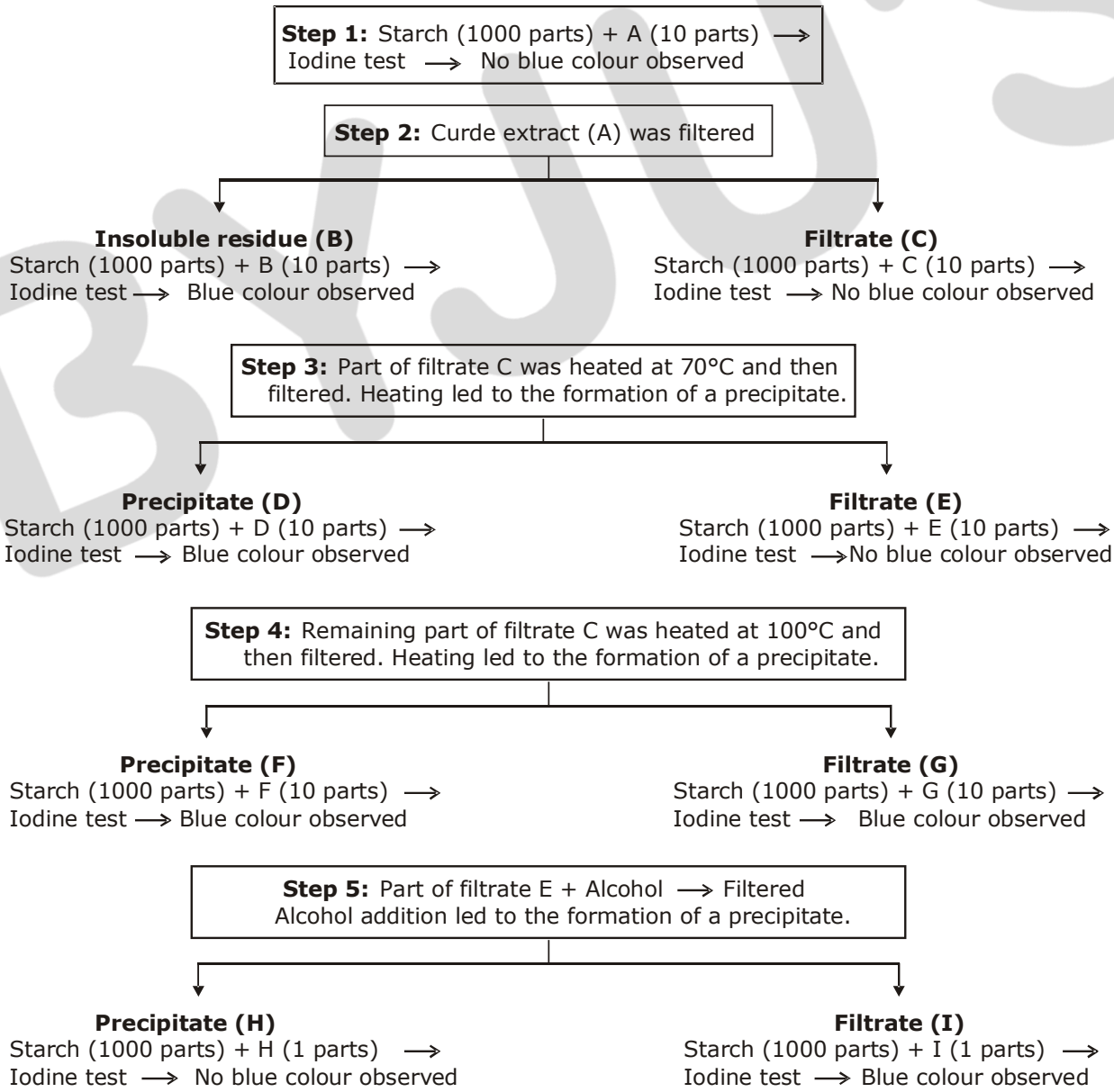
In the beginning of experiment when group 1 rats are kept hungry, the average error at the beginning would be higher than other groups . But as all the other conditions are kept the same, means they will be fed (rewarded) at finding the end of the maze; the end reward would be more motivational hence, the most appropriate event happening with respect to their performance would be steeper decrease in line 1.

Not -well fed rats (group 1-here) will show a large decrease in time and error scores. The drop in the error curve would be significantly below the curve of the control group (earlier well fed Group1) hence a steeper line 1 in lesser time.

17. (7 marks) In the early nineteenth century, two scientists Payen and Persoz ground barley seed 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 result 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 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 search to glucose but it gets destroyed by heat

(c) The substance present in barley seeds in 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?

Solution (17 to 17.3) :

17. Previous knowledge required to solve the quetsions :

The iodine–starch test was first described by J. J. Colin and H. F. Gaultier de Claubry, and independently by F. Stromeyer. The triiodide anion instantly produces an intense blue-black colour upon contact with starch.

It is observed that the helix (coil or spring) structure of the glucose chain is the key to this test. Further, the resulting color depends on the length of the glucose chains. The triiodide and pentaiodide ions formed are linear and slip inside the helix structure.

The intensity of the color decreases with the increase in temperature and the presence of water-miscible organic compounds like ethanol.

On heating, the blue color amylase-iodine complex dissociates but is formed again on cooling because the helical structure is disrupted; thereby amylose loses its iodine binding capacity and the blue color. The blue color reappears on cooling due to the recovery of iodine binding capacity due to regaining of the helical structure.

17.1 (D)

If a solution is giving positive iodine test ;i.e. appearance of Blue colour is there , then it indicates that the iodine is trapped in the intact polymer of starch. Because the helix (coil or spring) structure of the glucose chain/polymer of starch is the key to this test; the triiodide and pentaiodide ions formed are linear and slip inside the helical structure of the polymer.

17.2 **Statement (a)- FALSE :** Barley seeds contain a substance (enzyme- Diastase) that converts starch to monomers that is glucose ; not glucose to starch. Hence, this statement is false.

Statement (b)- FALSE : No, barley seed coat does not contains a substance (enzyme) that converts starch to glucose rather it is secreted when seed imbibes and begins to germinate the embryo produces a gibberellin which diffuses to the aleurone layer and stimulates the aleurone cells to synthesize enzymes (alpha-amylase) and secrete them into the starchy endosperm. But it gets destroyed by heat approximately above 100 degrees.

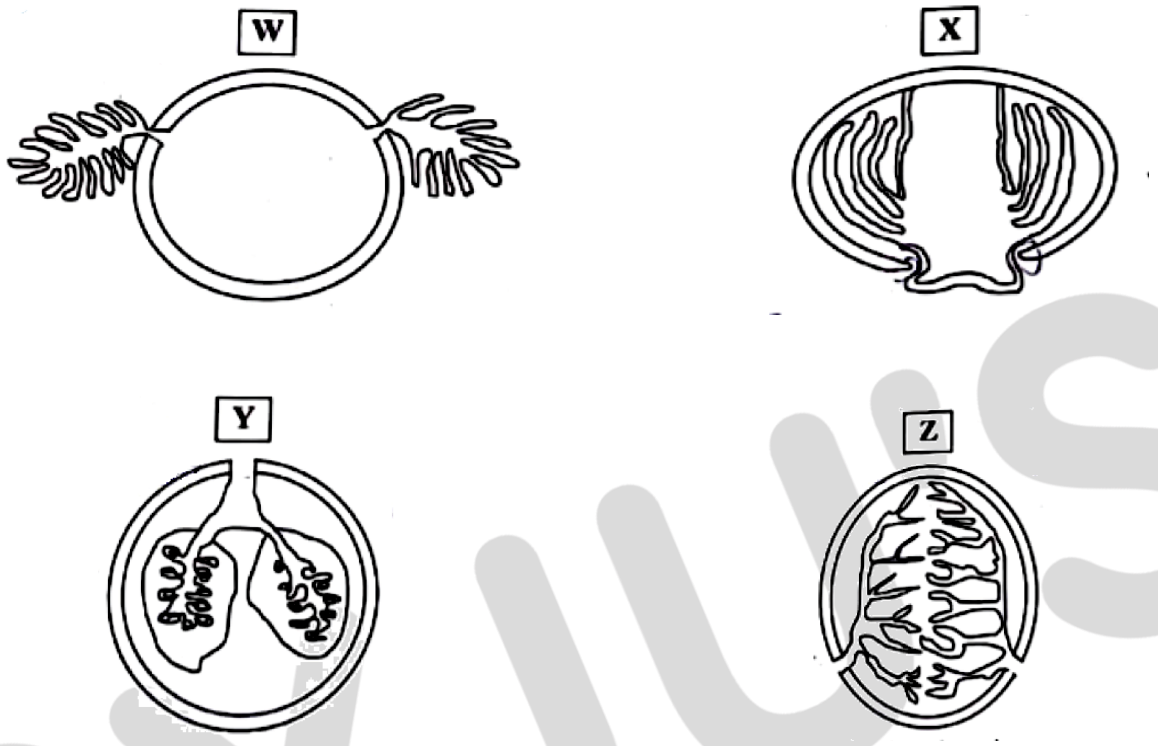
Statement (c)- TRUE : The substance (enzyme) in barley seeds is water soluble ; and it breaks starch into small units.

Statement (d)- TRUE : The process of heating up to 70 degree enhances the chemical activity of barley filtrate, evidenced by step number 3 in the question ; whereby even after heating ; enzymes was still present in filtrate (E) and also performed by dissolving the starch, hence giving no colour in iodine test. And heating above 70 degree inactivates the active substance in barley filtrate evidenced by step 4; where heating above 100 degree must have deactivated the active agent (Enzyme) and hence, starch is very much present in filtrate as well as precipitate, thereby giving positive iodine test.

17.3 Following preparations from A-I ; indicates presence of active substance (an enzyme – diastase ; Today, "diastase" refers to any α-, β-, or γ-amylase ;all of which hydrolases that can break down carbohydrates) being analyzed in barley.

Preparation $\rightarrow$ A; C; E and H.

18. (7 Marks) Different types of respiratory organs in animals occupying different habitats are represented in the figure (W–Z) given 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:

$Q = DA(P1 - P2) / L$

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 (eq., a gas), the medium and the temperature.

A = cross sectional area over which the gas is diffusing

P1 and P2 are the partial pressure 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 the 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)	Effected (increase/decrease/no change)	Effect on Q (increase/decrease no change)
1. Highly branched and folded extensions	-	-	-
2. Presence of very thin-walled tissues	-	-	-

Solution (18.1 to 18.3) :

18. Given Information in this question

Fick's law of diffusion : Q= D A (P1-P2)/L;

This equation tells us that for a given molecule diffusion rate is:

(a) Directly proportional to area of absorptive surface (A). Greater the area for diffusion, greater will be the rate of diffusion.

(b) Directly proportional to the concentration gradient(P1 - P2). The steeper the gradient, or in other words, greater the difference in concentration between two areas, greater the rate of diffusion will be.

(c) Indirectly proportional to the distance of travel (L). The longer the distance of travel the slower the rate of diffusion. So, there must be a short diffusion distance.

(d) Indirectly proportional related to the medium of travel (D). The more viscous and dense the medium, the slower the diffusion rate

18.1 Here figure W →respiratory organ of the tadpole→ external gills→Aquatic habitat

figure X → respiratory organ of the prawn→ internal gills→ Aquatic habitat

figure Y → respiratory organ of the rabbit → lungs→ Terrestrial habitat

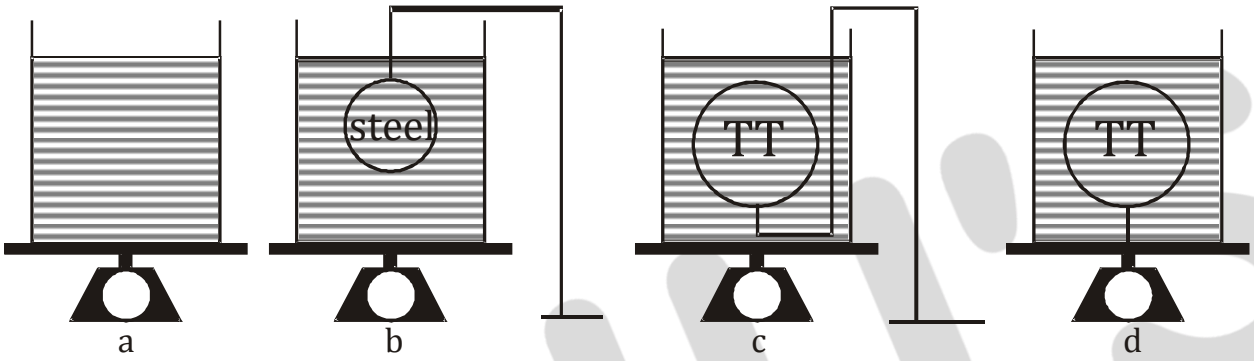
figure Z → respiratory organ of the cockroach→ spiracles→ Terrestrial habitat

18.2 Hereby we Kept the temp. of habitats of all given animals same.
Only based on the type of medium used for gas exchange, we have to find the value of Q.
According to Fick's law of diffusion → Q= D A (P1-P2)/L;
The diffusion rate is indirectly proportional related to the medium of travel (D). The more viscous and dense the medium is, slower the diffusion rate will be .
Higher value of D would be of animals possessing respiratory organs of types (a) =(Aquatic medium=more viscouse/dense) →animals W and X.
Lower value of D would be of animals possessing respiratory organs of types (b) = (Terrestrial medium/Air=less viscous/dense) → animals Y and Z.
As mentioned earlier that the Q, (the rate of diffusion of gases between two locations) is indirectly proportional to the medium of travel (D), the values of Q for W,X,Y and Z would be → lower value of Q would be of animals possessing respiratory organs of types (a) =(Aquatic medium) → animals W and X.
Higher value of Q would be of animals possessing respiratory organs of types (b) = (Terrestrial medium) → animals Y and Z.

18.3

Column I	**column II**	**column III**	**column IV**	**Reason accounted for change in**	**Reason accounted for change in**
Features	**Factors affected**	**Effect**	**Effect on Q**	**Column III**	**Column IV**
1. highly branched and folded extensions	**A**	**Increase**	**Increase**	Because highly branched and folded extensions increases the surface area many folds as compared to a less branched structure.	Because Q is directly proportional to area of absorptive surface (A). The greater the area for diffusion, then the greater the rate of diffusion.
2. presence of very thin walled tissues	**L**	**Decrease**	**Increase**	A thin walled tissue would provide gases with a short diffusion distance.	Because Q is indirectly proportional to the distance of travel (L). The longer the distance of travel the slower the rate of diffusion. So there must be a short diffusion distance.

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 0.020kg) 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 = 1kg, then obtain W_a , 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.

Sol. Given mass of the steel ball = 0.800 kg

Mass of TT ball = 0.020 kg

Volume of each ball = 10^{-4} m^3

For beaker a:- Normal force for the only water $N_a = 1 \times 10$

$\therefore$ Reading of pan for a (W_a) = 1 kg

For beaker b:- Normal force can be calculated as

$$N_b = Mg + \rho gV$$

$$N_b = 10 \times 1 + 10^3 \times 10 \times 10^{-4}$$

So, reading of pan for b (W_b) = $\frac{10 \times 10^4 \times 10^{-4}}{10} = \frac{11}{10} = 1.1\text{kg}$

Similarly, for beaker c:-

Normal force $N_c = Mg + \rho gV$

$N_c = 10 \times 1 + 10^3 \times 10 \times 10^{-4}$

So, reading of pan for c (W_c) = $\frac{10 \times 10^4 \times 10^{-4}}{10} = \frac{11}{10} = 1.1\text{kg}$

for beaker (d) :-

Normal force (N_d) = $Mg + m_T g$; m_T = mass of TT ball

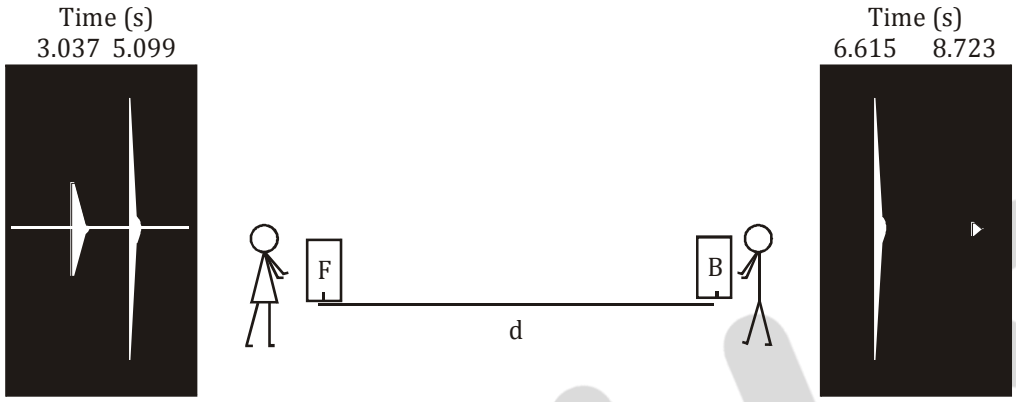
$= 1 \times 10 + 0.02 \times 10$

$\therefore$ So, reading of pan for d (W_d) = $\frac{10 + 0.2}{10} = \frac{10.2}{10} = 1.02\,\text{kg}$

So, we can say that

$W_b = W_c > W_d > W_a$

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 smartphones 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.

Sol. From the figure we can say that when Fatima clap the intensity of sound will be maximum and that is recorded by the app at time 5.099 s.

This sound wave will propagate and travel towards the Bharat and recorded at the time 8.723 se(C)

Now when Bharat claps at 6.615 s, its intensity will be maximum but due to the time difference, Fatima is not able to record the Bharat's clap.

So only Fatima's clap or the reading of Fatima is fully available

i.e. time (t) = 5.099, 8.723

So, distance between Fatima and Bharat

$d = (8.723 - 5.099) \times 363$

$d = 1315.512$ m.

21. (6Marks) With about half of its surface always having day, Earth constantly receives heat from the Sun and maintains an average temperature of 288K. 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 question, make suitable assumptions wherever needed.

21.1 Estimate h.

21.2 The fresh water requirement is about 6800 I/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.

Solution (21.1 to 21.2)

21.1. (A)

Given:- Average power goes into the evaporation of water = 40.3×10^{16}W

So, for 1 sec energy can be calculated as $E = \frac{P}{t} = \frac{4.3\times10^{16}}{1} = 4.3\times10^{16}$ J

which is used as in terms of heat.

Now, for water when it goes from 15°C to 100° C

$\Rightarrow 4.3\times10^{16} = M[s\Delta T + mL]$

$\Rightarrow 4.3\times10^{16} = M[85\times4200 + 2268\times10^{3}]$

$\Rightarrow M = \frac{4.3\times10^{16}}{2625\times10^{3}}$

It is the mass evaporated in 1sec

Now, mass evaporated in 1 year can be calculated as

$M = \frac{4.3\times10^{16}}{2625\times10^{3}}\times365\times24\times60\times60$ ...(1)

Let there be a shell of thickness h near the surface of the earth.

So, mass of the shell formed will be = $\rho\times$ volume

$M = \rho\times V$ ...(2)

From equations (1) and (2),

$\frac{4.3\times10^{16}}{2625\times10^{3}}\times365\times24\times60\times60 = 10^{3}\times4\times3.14\times(64)^{2}\times h\times10^{10}$

After calculation,

h = 1 meter

21.2. (B)

$\text{Ratio} = \frac{\text{Water required annually for earth}}{\text{annual rain fall}}$

Water required = $6800\times800\times10^{7}\times365$

Annual water received from rain fall = $4\times\frac{22}{7}\times(64)^{2}\times10^{4}\times\frac{1}{10^{3}}$

$\therefore$ Ratio = 365×10^{8}