INDIAN NATIONAL JUNIOR SCIENCE OLYMPAID -2020

Questions Paper **INJSO - 2020**

Roll Number: | | | | | | | | | | | | |

Date: 1st February 2020

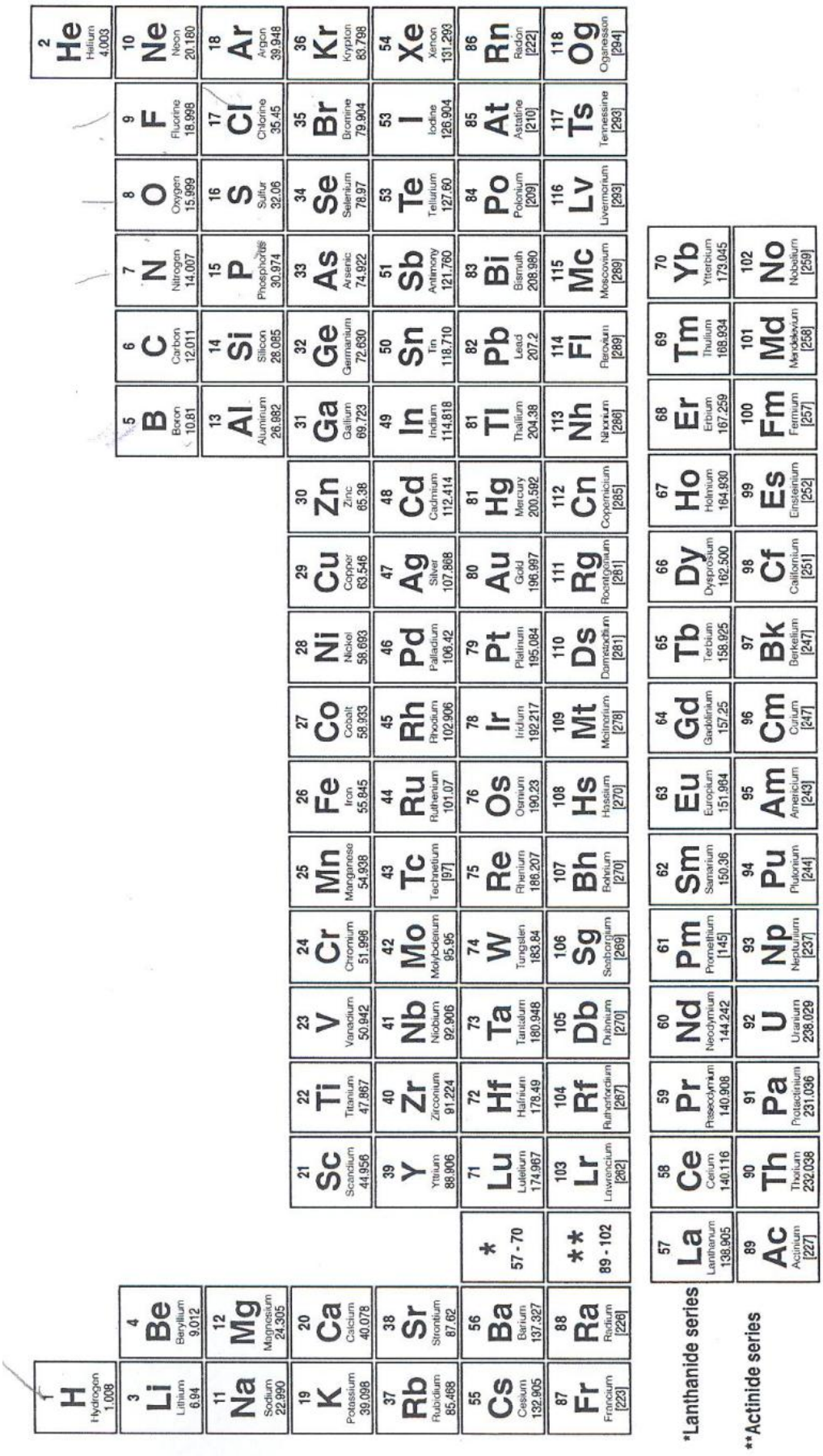
Duration: **Three Hours** Maximum Marks: 180

Please Note:

- Please write your roll number on top of this page in the space provided.
- Use of non- programmable scientific calculators is allowed.
- **The answer- sheet must be returned to the invigilator. You can take this question paper back with you.**
- Section I of this question paper has 15 questions.
  - For each question in this section, only one of the four options is a correct answer.
  - For each question, a correct answer will earn 3 marks, a wrong answer will earn (–1) mark, and an unattempted question will earn 0 marks.
  - If you mark more than one option, it would be treated as a wrong answer.
- Section II contains 9 question wroth 5 marks each. There is no negative marking.
  - For questions 16 to 21, one or more option(s) may be correct.
  - If you mark all correct options and no wrong option, you get full credit (5 marks).
  - If you mark some correct options and no wrong option, you get 2 marks.
  - If you mark any wrong option, you get zero marks.
- For questions 22 to 24, only write your final answer in corresponding spaces in the answer sheet. No explanation / calculations are necessary.
- Section III contains 11 questions.
  - For all the questions in this section, the process involved in arriving at the solution is more important than the final answer. Valid assumptions / approximations are perfectly acceptable. Please write your method clearly, explicitly stating all the reasoning / assumptions / approximations.
  - In case you fall short of writing space for any question, you can ask for an extra sheet. You can ask for maximum of two extra sheets.

Useful Constants

Gravitational Constant	$G \approx 6.674 \times 10^{-11}\ Nm^2/Kg^2$
Gravitational Acceleration	$g \approx 9.80\ m/s^2$
Avogadro's number	$N_A \approx 6.022 \times 10^{23}/mol$
Universal Gas Constant	$R \approx 8.3145\ J/(mol\ K)$
Atmospheric Pressure	$1\ atm \approx 101325\ Pa$


1 H Hydrogen 1.008
3 Li Lithium 6.94
4 Be Beryllium 9.012
11 Na Sodium 22.990
12 Mg Magnesium 24.305
19 K Potassium 39.098
20 Ca Calcium 40.078
37 Rb Rubidium 85.468
38 Sr Strontium 87.62
55 Cs Cesium 132.905
56 Ba Barium 137.327
87 Fr Francium [223]
88 Ra Radium [226]
* 57 - 70
** 89 - 102
21 Sc Scandium 44.956
39 Y Yttrium 88.906
71 Lu Lutetium 174.967
103 Lr Lawrencium [262]
22 Ti Titanium 47.867
40 Zr Zirconium 91.224
72 Hf Hafnium 178.49
104 Rf Rutherfordium [267]
23 V Vanadium 50.942
41 Nb Niobium 92.906
73 Ta Tantalum 180.948
105 Db Dubnium [270]
24 Cr Chromium 51.996
42 Mo Molybdenum 95.95
74 W Tungsten 183.84
106 Sg Seaborgium [269]
25 Mn Manganese 54.938
43 Tc Technetium [97]
75 Re Rhenium 186.207
107 Bh Bohrium [270]
26 Fe Iron 55.845
44 Ru Ruthenium 101.07
76 Os Osmium 190.23
108 Hs Hassium [270]
27 Co Cobalt 58.933
45 Rh Rhodium 102.906
78 Ir Iridium 192.217
109 Mt Meitnerium [278]
28 Ni Nickel 58.693
46 Pd Palladium 106.42
79 Pt Platinum 195.084
110 Ds Darmstadtium [281]
29 Cu Copper 63.546
47 Ag Silver 107.868
80 Au Gold 196.997
111 Rg Roentgenium [281]
30 Zn Zinc 65.38
48 Cd Cadmium 112.414
81 Hg Mercury 200.592
112 Cn Copernicium [285]
5 B Boron 10.81
13 Al Aluminium 26.982
31 Ga Gallium 69.723
49 In Indium 114.818
81 Tl Thallium 204.38
113 Nh Nihonium [286]
6 C Carbon 12.011
14 Si Silicon 28.085
32 Ge Germanium 72.630
50 Sn Tin 118.710
82 Pb Lead 207.2
114 Fl Flerovium [289]
7 N Nitrogen 14.007
15 P Phosphorus 30.974
33 As Arsenic 74.922
51 Sb Antimony 121.760
83 Bi Bismuth 208.980
115 Mc Moscovium [289]
8 O Oxygen 15.999
16 S Sulfur 32.06
34 Se Selenium 78.97
53 Te Tellurium 127.60
84 Po Polonium [209]
116 Lv Livermorium [293]
9 F Fluorine 18.998
17 Cl Chlorine 35.45
35 Br Bromine 79.904
53 I Iodine 126.904
85 At Astatine [210]
117 Ts Tennessine [293]
2 He Helium 4.003
10 Ne Neon 20.180
18 Ar Argon 39.948
36 Kr Krypton 83.798
54 Xe Xenon 131.293
86 Rn Radon [222]
118 Og Oganesson [294]
57 La Lanthanum 138.905
58 Ce Cerium 140.116
59 Pr Praseodymium 140.908
60 Nd Neodymium 144.242
61 Pm Promethium [145]
62 Sm Samarium 150.36
63 Eu Europium 151.964
64 Gd Gadolinium 157.25
65 Tb Terbium 158.925
66 Dy Dysprosium 162.500
67 Ho Holmium 164.930
68 Er Erbium 167.259
69 Tm Thulium 168.934
70 Yb Ytterbium 173.045
89 Ac Actinium [227]
90 Th Thorium 232.038
91 Pa Protactinium 231.036
92 U Uranium 238.029
93 Np Neptunium [237]
94 Pu Plutonium [244]
95 Am Americium [243]
96 Cm Curium [247]
97 Bk Berkelium [247]
98 Cf Californium [251]
99 Es Einsteinium [252]
100 Fm Fermium [257]
101 Md Mendelevium [258]
102 No Nobelium [259]
*Lanthanide series
**Actinide series

HINTS & SOLUTIONS

SECTION - I

1. A body with a density ρ is attached to a spring that is known to stretch linearly with the applied force. The spring is held vertically such that the body is fully immersed in a liquid of density ρ_1 ($< \rho$). In this case, the spring stretches by a length x_1. When the same body is fully immersed in a liquid of density ρ_2 ($< \rho_1$), the spring stretches by x_2. This implies that the density of the body (ρ) is given by the expression

A. $\frac{\rho_1 x_1 - \rho_2 x_2}{x_1 - x_2}$ B. $\frac{\rho_1 x_2 - \rho_2 x_1}{x_2 - x_1}$ C. $\frac{\rho_1 x_2 + \rho_2 x_1}{x_1 + x_2}$ D. $\frac{\rho_1 x_2 - \rho_2 x_1}{x_1 - x_2}$

Sol. **B**

As per equilibrium condition T + B = W

$Kx_1 + \delta_1 Vg = \delta Vg$

$Kx_1 = \delta Vg - \delta_1 Vg$ … (1)

Similarly

$Kx_2 = \delta Vg - \delta_2 Vg$ … (2)

Dividing (1) by (2) we get

$$\frac{x_1}{x_2} = \frac{\delta - \delta_1}{\delta - \delta_2}$$

Solve & ve get

$$\delta = \frac{\delta_1 x_2 - \delta_2 x_1}{x_2 - x_1}$$

2. For any conductor, the thermal dependence of resistance is given by $R = R_0\{1 + \alpha(\Delta\theta)]$, where $\Delta\theta$ is the temperature difference in °C, α is a constant having the dimensions of T^{-1} and R_0 is the resistance of the wire at 0°C.

A wire made of a conductor, with $\alpha < 0$, is subjected to a constant voltage V. Then, for the wire, as the time progresses.

A. the temperature as well as the current will go on decreasing

B. the temperature will go on decreasing while the current will go on increasing

C. the temperature as well as the current will go on increasing

D. the temperature will go on increasing while the current will go on decreasing.

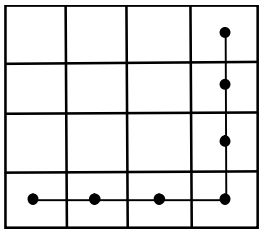
Sol. **C**

As $\alpha < 0$ so on increasing the temperature, R will decreasing so current will increasing and as the time passes, the heat will be generated causing temperature to rise.

3. On a standard chess board with (8 * 8) squares, a chess piece starts to move from the lower left corner, which we shall label as square (1 * 1). This piece is allowed to move only upwards or rightwards. At any point, the piece cannot move downwards, leftwards or diagonally, e.g., from square (2 * 3), the piece may go towards (3 * 3) or (2 * 4) but not any other direction. If this piece continues to move only according to these rules, the number of different paths by which it can reach the square (4 * 4), starting from the square (1 * 1), is

A. 16 B. 18 C. 20 D. 24

Sol. **C**



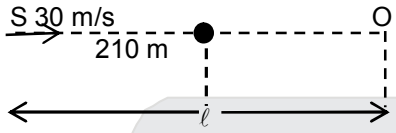
To move the chess piece from square (1 × 1) to square (4 × 4) we need to move 3 Horizontal (HHH) and 3 Vertical (VVV) moves and which can be arranged in $\frac{6!}{3!3!}$ = 20 ways.

4. A train is move at a speed of v = 108 km/h towards a person standing just next to the rails. The train blows a whistle for 7.0 s. What is the time duration for which the whistle is heard by this person? Assume that the train does not reach or cross the person until the end of whistle. Speed of sound in air is 350 m/s.

A. 6.4 s B. 7.6 s C. $\frac{245}{38}$ s D. $\frac{245}{32}$ s

Sol. **A**

t = 0



first wave detected

$t_1 = \frac{\ell}{350}$

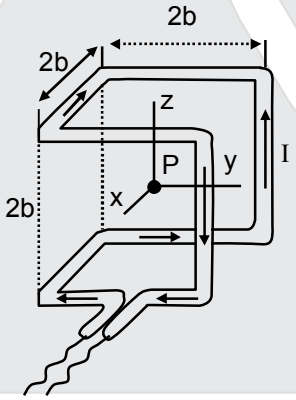
last wave detected

$t_2 = \frac{\ell - 210}{350}$

$\Delta t = t_1 - t_2 = \frac{210}{350} = \frac{3}{5} = 0.6$

Time duration = 7 – 0.6 = 6.4 s.

5. A current carrying wire is bent in the shape shown below. Direction of current is also shown in the figure. The direction of magnetic field at the center P of the cubical shape will be



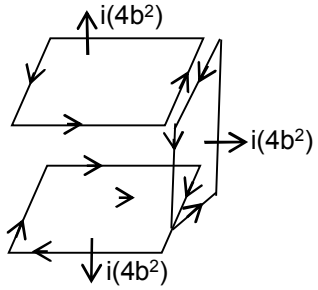
A. parallel to the x-axis B. parallel to the y-axis
C. parallel to the z-axis D. undefined (field will be zero)

Sol. **B**

Net magnetic field will be along the net moment.

So, the direction of magnetic field at P.

Parallel to Y- axis



6. In the balanced chemical equation of the thermal decomposition of lead (II) nitrate to lead (II) oxide, if the coefficient of lead (II) nitrate is 2, then the coefficient of nitrogen dioxide is

A. 1 B. 2 C. 3 D. 4

Sol. **D**

$2\ Pb(NO_3)_{2\ (s)} \xrightarrow{\Delta} 2PbO_{(s)} + 4NO_{2\ (g)} + O_{2\ (g)}$

7. Metals react with oxygen to form metal oxides. If the metals considered are K, Cs, Mg and Sr, the correct order of the basic character of their oxides is :

A. $MgO > SrO > K_2O > Cs_2O$ B. $Cs_2O < K_2O < MgO < SrO$

C. $MgO < SrO < K_2O < Cs_2O$ D. $K_2O < MgO < SrO < Cs_2O$

Sol. **C**

In a group, moving top to bottom basic nature of metallic oxide increase

$K_2O < Cs_2O$

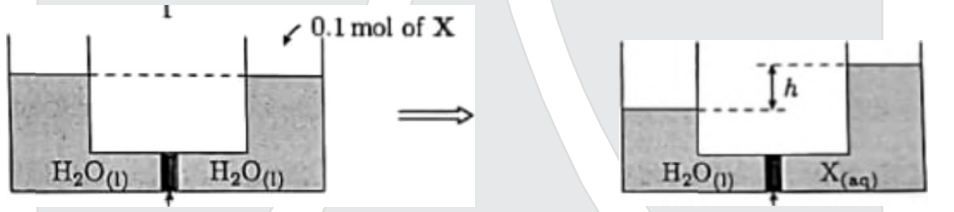
$MgO < SrO$

Alkali metal oxides are more basic than alkaline earth metal. SO

$MgO < SrO < K_2O < Cs_2O$

8. A U-shaped tube with a semipermeable membrane is filled with 2 L of water as shown in figure 1. When 0.1 mol of compound X is completely dissolved in the right arm of the tube, the level of X(aq) solution rises as shown in the figure II. Assume that the rise in the solution level is proportional to the number of solute particles in an aqueous solution.

I II



Semipermeable membrane Semipermeable membrane

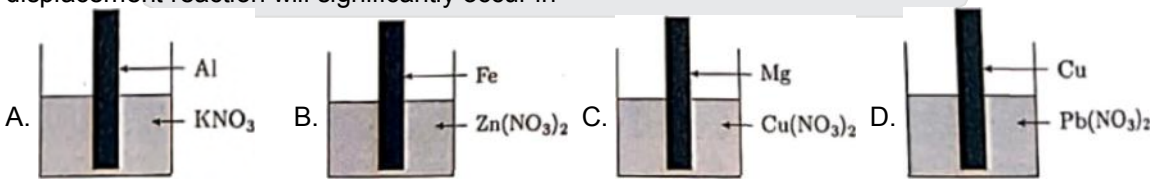
The height ***h*** would be the highest when X is

A. $MgCl_2$ B. CH_3COOH C. NH_4NO_3 D. Cane Sugar

Sol. **A**

After dissociation $MgCl_2$ maximum no. of ions will going to produce [3]. As we know osmotic pressure is a colligative property and only depends on the no. of particles, and $MgCl_2$ contain maximum no of particle, so movement will be maximum.

9. A more reactive metal displaces a less reactive metal from its salt solution. Observe the following figures in which a metal rod is suspended in 1 M salt solution. At room temperature, the displacement reaction will significantly occur in



Sol. **C**

According to reactivity series, Mg is more reactive than Cu. so,

$Mg + Cu(NO_3)_2 \longrightarrow Mg(NO_3)_2 + Cu$

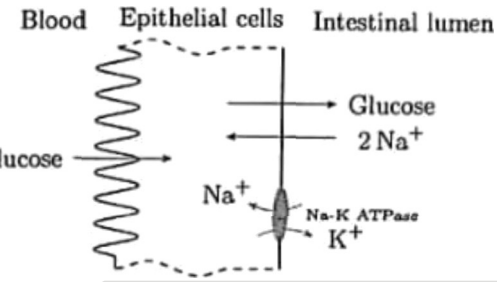
10. Soaps are sodium salts of fatty acids. Which of the following can be added to a pure soap to bring its pH to 7?

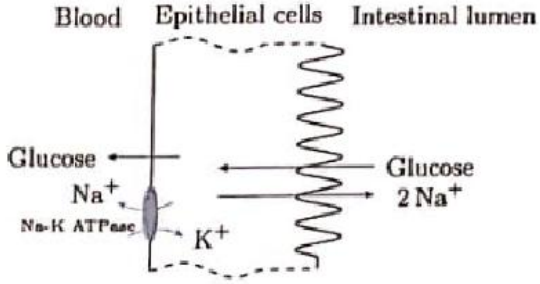
A. Lemon Juice B. Common salt C. Sodium Nitrate D. Baking Soda

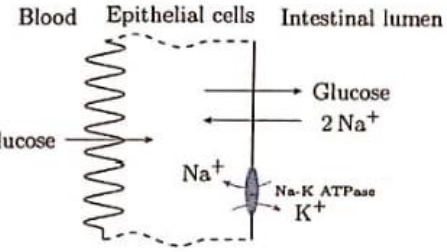
Sol. **A**

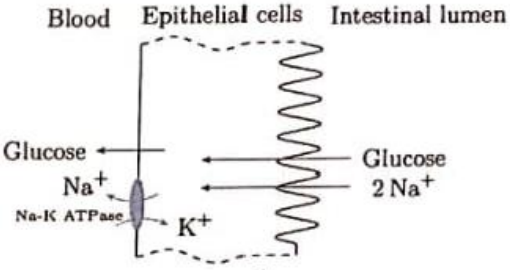
Pure soap has pH more than 7, so to bring its pH to 7 we can add acidic substance in it we can add lemon juice to it.

11. In case of diarrhea, oral rehydration salts (OHS) mixed with water is used as a simple therapy to rehydrate the patient. Rehydration occurs only if glucose and NaCl (both present in ORS) are added to water and given to the patient. Which of the diagrams given below correctly represents the initial steps in the working of ORS in the intestine?

A.


B.


C.


D.


Sol. **D**

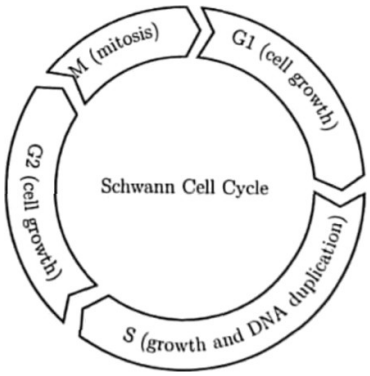
12. Two populations of a land species were effectively isolated from each other for a long period of time. Which of the following would demonstrate that the two populations have evolved into separate species?

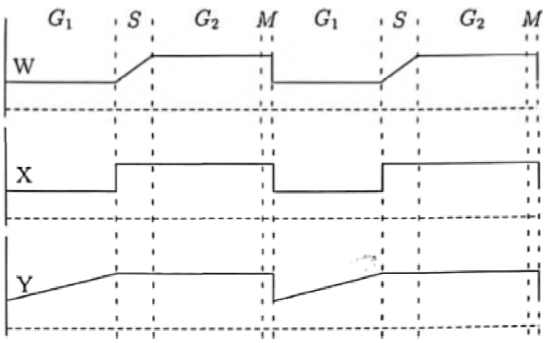
A. The two populations differ in at least five morphological traits.
B. Sterile hybrids are produced when members of the two populations mate.
C. Organisms of both the populations do not willingly mate with each other.
D. DNA sequences are different for the two populations.

Sol. **C**

13. The figure on the right represents the cell cycle for Schwann cells. As Schwann cells grow, they remain metabolically active for a certain period of time and then either undergo apoptosis (cell death) or divide and form new daughter cells. Actively dividing cells undergo a normal cell cycle as shown in the diagram. A newly formed cell passes through G_1, S, G_2 phases, together called 'interphase', before entering mitotic division phase (M phase). Mitosis gives rise to two new daughter cells which are genetically identical to the mother cell.

Among the graphs shown below, one represents the trend shown by the 'cell volume' during the cell cycle and another represents the trend show it by the 'amount of genomic DNA'. Identify the two graphs in the same order.





A. Y and W B. Y and X C. Z and X D. Z and W

Sol. **D**

14. Chromophores are commonly used as biological stains to view cell organelles better. When an epithelial cell (e.g. skin cell) is stained with a basic dye like methylene blue and observed under a light microscope (total magnification of 100 X), the visible cell organelle(s) will be

A. Blue nucleus and blue mitochondria. B. Blue nucleus and blue endosomes.
C. Blue nucleus and pink mitochondria. D. Blue nucleus.

Sol. **D**

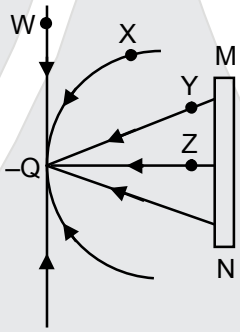
15. Alleles are variant forms of a gene that are located at the same position, or genetic locus, on a chromosome. An allele frequency is calculated by dividing the number of times the allele of interest is observed in a population by the total number of all the alleles at that particular genetic locus in the population. A cross is made between two pea plants, one bearing round seeds and the other bearing wrinkled seeds. All pea plants in the F_1 progeny had round seeds. When the F1 progeny were self-pollinated and the F_2 progeny analyzed, it was observed that 300 plants had round seeds while 100 plants had wrinkled seeds. What is the frequency of the dominant allele that IS responsible for seed shape in the F_2 progeny?

A. 25% B. 250% C. 75% D. 100%

Sol. **B**

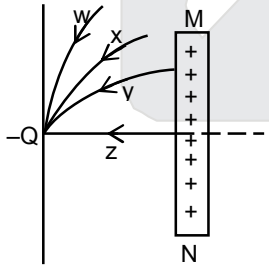
SECTION - II

16. The figure on the right shows a negative point charge (– Q) and a thick uncharged metal plate. In the two dimensional figure, MN is a cross section of the plate. As seen in the figure, the charge is located on the normal drawn from the centre of the plate.
A student was given this situation and was asked to draw lines of force through the points W, X, Y and Z. The diagram on the right is the answer given by the student. At which point(s) the drawn lines of force definitely do(es) NOT match the actual lines of force



A. W B. X C. Y D. Z

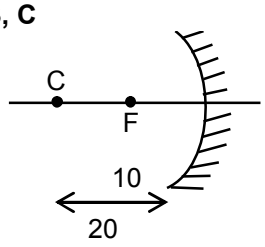
Sol **A, C**



17. A 5 cm long needle is placed along the principal axis of a concave mirror of a focal length 10 cm. It is observed that one end of the image of the needle coincides with one of the ends of the needle. The other end of the image is at a distance x from the pole of the mirror, where x is

A. 20 cm B. $\frac{50}{3}$ cm C. 30 cm D. 10 cm

Sol. **B, C**



Case - I

u = – 25 cm

f = – 10 cm

$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$v = \frac{uf}{u-f} = \frac{(-25)(-10)}{-25+10}$

$= \frac{250}{-15} = -\frac{50}{3}$ cm

Case – II

u = – 15 cm

f = – 10 cm

$v = \frac{uf}{u-f} = \frac{(-15)(-10)}{-15+10} = -30$ cm

18. A body is performing one dimensional motion. After time instant $t = t_1$, the body covers equal distances in two successive time intervals Δt_1 each. Also, the speed of the body at time instant $t = t_1$ and at $t = t_1 + 2\Delta t_1$ happens to be the same. Therefore, the

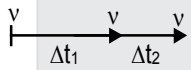
A. acceleration may be zero

B. body may be moving with a constant non-zero acceleration

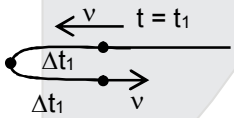
C. body may be moving with an acceleration proportional to displacement (from a suitable defined origin) and directed opposite to it.

D. body may be coming to a halt momentarily

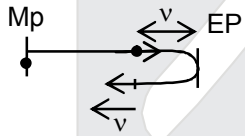
Sol. **A, B, C, D**

(A) 

a = 0 straight line motion.

(B) 

In case constant acceleration in opposite direction to initial velocity.

(C) 

In case of SHM

(D) At turning point $v = 0$

19. 3.0 g of ethanoic acid reacts with 1.84g of absolute ethanol in the presence of an acid catalyst to give an ester. Assuming that the reaction goes to completion, the correct statement(s) is/are

A. 0.05 mol of ester is formed.

B. 3.5 g of ester is produced.

C. 24×10^{21} molecules of ester are produced.

D. The product contains 9.6×10^{22} carbon atoms.

Sol. **B, C, D**

$CH_3COOH + C_2H_5OH \xrightarrow{conc.H_2SO_4} CH_3COOC_2H_5 + H_2O$

1 mole	1 mole	1 mole	1 Mole
60 g	46 g	88 g	18g

Mole = $\frac{3}{60} = 0.05$ $\quad \frac{1.84}{46} = 0.04$

LR = $\frac{0.05}{1}$ $\quad \frac{0.04}{1}$

So Limiting reagent is C_2H_5OH

$\because$ 46 g of C_2H_5OH gives = 88 g of ester

1.84 g of C_2H_5OH gives = $\frac{88}{46}\times 1.84$ = 3.52 g

No. of molecules of ester = $\frac{3.52}{88} \times N_A$ molecules

= 24 × 10^{21} molecules

No. of mole. Of ester = $\frac{3.52}{88}$ = 0.04 moles

So no. of carbon atoms = 0.04 × $4N_A$

= 9. 6 × 10^{22} carbon atoms

20. One mole of $^{14}_{7}N^{3-}$ ions contains

A. $10N_A$ electrons B. $4N_A$ protons C. $7N_A$ neutrons D. $7N_A$ protons

Sol. **A, C, D**

1 mole of $^{14}_{7}N^{3-}$ ions contains

No. of neutron = 14 – 7 = $7N_A$

In 1 mole of N^{3-}

No. of electrons in 1 mole of N^{3-} = $10N_A$

No. of protons in 1 mole of N^{3-} = $7N_A$

21. Q, X, Z, J, E, L and G are some unknown elements. The pair(s) that show similar chemical properties is/are

A. $_5Q$, $_{19}X$ B. $_{12}Z$, $_{38}J$ C. $_9E$, $_{15}L$ D. $_{20}G$, $_{12}Z$

Sol. **B, D**

Similar chemical properties means elements will be belong to same group. So,

$_{12}Z$, $_{38}J$ and $_{20}G$, $_{12}Z$

Here Z = Mg G = Ca J = Sr

22. Karl Landsteiner (1868-1943) discovered the A, B and O blood groups in 1901, which was followed by the identification of AB blood group in 1902 by his student Struli. The ABO blood group system is based on the presence or absence of antigen A and / or B on the RBCs. Antibodies to A and B antigens are present or absent in the plasma, depending on the antigen which is present on the RBCs of an individual. Antibodies are generated in individual against a foreign antigen, but not against an antigen that is inherently present in the individual. If RBCs carrying an antigen (say A) is mixed with a plasma carrying antibodies against the antigen (say anti-A), the RBCs will agglutinate (clump). In an experiment, the RBCs and plasma were separated from five different individuals (P to T) and were mixed in different combinations as shown in the table below, which either resulted in agglutination (+) or no agglutination (-).

		Plasma from individuals				
		P	Q	R	S	T
RBC from individuals		–	+	+	–	+
	Q	+	–	+	–	+
	R	–	–	–	–	–
	S	+	+	+	–	+
	T	+	–	+	–	–

if it is known that individual Q has antibodies against antigen A, identify the blood groups of all the five individuals.

Sol.

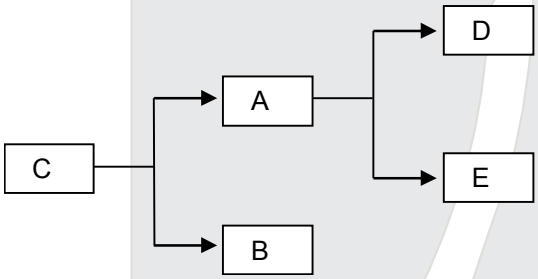
Individual		**Blood Group**
P	→	A
Q	→	B
R	→	O
S	→	AB
T	→	B

23. Molecular phylogeny is used to trace the changes in DNA or protein backwards in time to find out when each change led to divergence. The following are the amino acid sequences of a protein derived from the DNA sequences of 5 different organisms (sequences A to E).

K	N	S	Y	S	G	G	R	C	S	I	I	R	-Sequence A
K	N	S	Y	N	G	S	R	C	S	I	I	R	-Sequence B
K	N	S	Y	N	G	G	R	C	S	I	I	R	-Sequence C
K	N	S	Y	S	G	G	R	R	S	I	I	R	-Sequence D
K	N	S	Y	S	G	G	R	C	S	T	I	R	-Sequence E

How would you label the tree diagram below, which explains the evolution of this protein?
Note: The most ancestral form of the sequence should be at the origin (leftmost box). Assume that each step involves one change.

Sol.

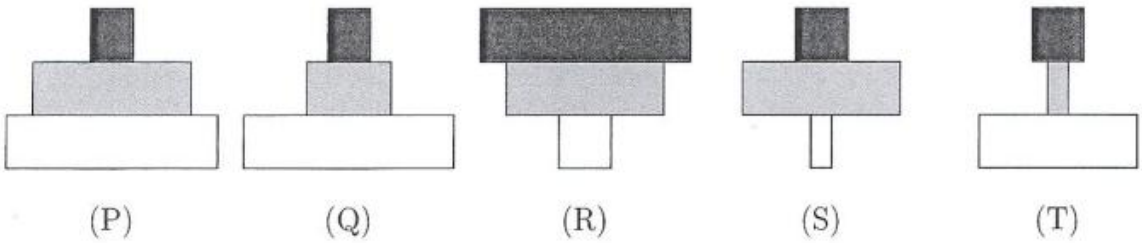


24. An ecological pyramid is a diagrammatic representation of the relationship between various organisms in an ecosystem. These pyramids can be drawn to represent the organic maerial (biomass), or number, or energy at each trophic level.
We list here four different ecosystems (i to iv) and five different ecological pyramids (P to T).
Match the ecosystems with the correct pyramids.

Ecosystems:

i. Number pyramid of an ecosystem consisting of grasses, snails amid mice.
ii. Number pyramid of an ecosystem consisting of a tree, caterpillars and mynas.
iii. Biomass pyramid of an ecosystem consisting of a tree, caterpillars and mynas.
iv. Number pyramid of an ecosystem consisting of a rose bush, aphids and parasites.

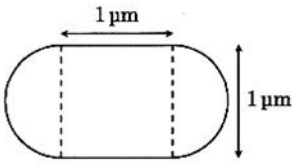
Pyramids:



Sol. (i) → (Q)
(ii) → (S)
(iii) → (P)
(iv) → (R)

SECTION - III

25. **(6 marks)** Consider a toy model of E.coli cell (bacterial cell) as a cylindrical body with hemispherical caps at both ends of the cylinder. The diameter of this cylinder is taken as 1 μm and the length of its cylindrical part is also 1 μm (See the figure on the right).

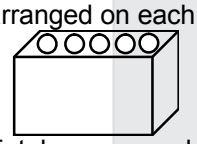


(a) Estimate the average distance between two E.coli cells (centre to centre distance) in a saturated growth medium having saturation density of E.coli cells of about 10^9 cells/mL.

(b) Many biochemical studies specify the concentration of proteins in a cell in units of nanomolar (nM) concentration. If such a protein species inside an E.coli cell has a concentration of at least 20nM, how many minimum molecules of that protein species are present in each cell?

Sol.

(a) Considering $1cm^3$ volume of cell group having homogenious cell arrangement. Let n cells are arranged on each axis having average seperation distance d.



Total average volume = $(nd)^3 = n^3d^3$

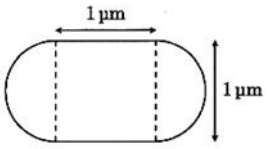
As per the question $n^3 = 10^9$ cells in each cm^3

so $n^3d^3 = 1cm^3$

$\Rightarrow d^3 = \frac{1}{10^9}\ cm^3$

$d = 10^{-3}$ cm

(b) Volume of one cell



r = 0.5 μm , L = 1μm

$V = \frac{4}{3}\pi r^3 + \pi r^2 l = \frac{4}{3}p\ (0.5 \times 10^{-6}) + p(0.5 \times 10^{-6})^2 \times 10^{-6}$

Volume of one cell = 1.308×10^{-12} mL

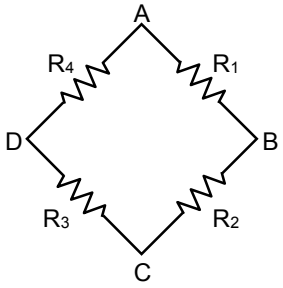
Concentration of protein species inside cell = 20nM

Number of mole protein = $20 \times 10^{-9} \times 1.308 \times 10^{-12} \times 10^{-3}$

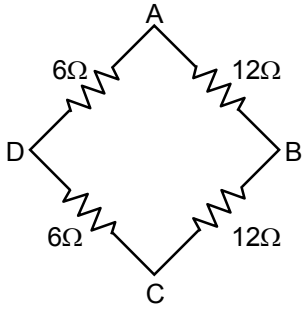
Number of molecules of protein = $20 \times 10^{-9} \times 1.308 \times 10^{-12} \times 10^{-3} \times 6.023 \times 10^{23} = 157.561 \times 10^{-1} = 15.75$

26. **(5 marks)** Resistances R_1, R_2, R_3 and R_4 are electrically connected between points A, B, C and D as shown the given figure. Their individual values can either be 6Ω or an integral multiple of 6Ω (All need not be different).

A multimeter connected between points A and C reads 8Ω (say, $R_{AC} = 8\Omega$). Calculate R_{AB}, R_{BC}, R_{CD}, R_{DA} and R_{BD}.

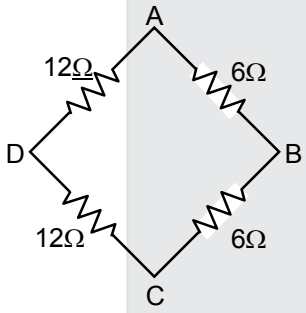


Sol.



$R_{AB} = 12\Omega$
$R_{BC} = 12\Omega$
$R_{CD} = 6\Omega$
$R_{DA} = 6\Omega$
$R_{BD} = 9\Omega$

OR



$R_{AB} = 6\Omega$
$R_{BC} = 6\Omega$
$R_{CD} = 12\Omega$
$R_{DA} = 12\Omega$
$R_{BD} = 9\Omega$

27. **(4 marks)** Read each of the following passages and point out, with a short justification (2-3 lines), the scientific mistakes, if any

(a) A spherical lens is a transparent medium bound by spherical surface. A glass marble can therefore be considered as a lens. Consider a glass marble (refractive index 1.50) of radius 15.00 mm. Using the geometrical optics formulae taught in high school. Prajakta calculated the focal length of this marble to be 15.00 mm. Consider a group of parallel ray incident on the marble. These rays will pass through the marble and get converged at 15.00 mm on the other side.

(b) A ray of white light is incident on a rectangular slab at an angle i. When the ray enters the glass slab from one surface, dispersion takes place. In other words, since the refractive index of glass is different for different constituent colours of white light, the angles of refractive are different, say r_{violet}, r_{indigo}, r_{blue}, etc. After travelling along different directions inside the glass slab, the ray of different colours will be incident on the glass air interface at the opposite parallel surface, at different angles of incidence. The rays of different colours will then leave this surface with different angles of refraction. Therefore, when white light passes through a glass slab, the constituent colours will spread out in different directions while leaving the slab.

Sol.

(a) **Error** Geometrical optics formula taught in high school are not applicable for marginal rays but applicable only for paraxial rays.

(b) **Error (1)** As refraction angle from first surface is different. So angle of incidence at second surface will also be different for different colours.
Error (2) As refraction all rays become parallel to each other so will no spread out in different directions while leaving the slab. So no dispersion will take place through glass slab.

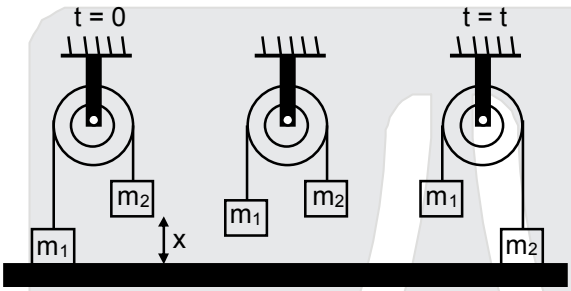
28. **(15 marks)** The free body diagram (a diagram that shows forces on individual objects) for an Atwood's machine (a system with a rope passing over a fixed pulley, with two masses attached at either end of the rope - see the figure) yields the following equation :

$$(m_2 - m_1)g = (m_2 + m_1)a$$

where a is the acceleration of the system of masses m_1 and m_2.

The following data were recorded for any Atwood's machine, with the total mass $(m_1 + m_2)$ being kept constant. Each reading corresponds to a different value of the mass difference $(m_2 - m_1)$ as shown in the table. In each case, at t = 0, the mass m_1 was resting on the ground below and the mass m_2 was at a height of x = 1.00m. The time recorded in the data table is the taken for the mass m_2 to hit the ground.

Using the given data and equation of motion, plot a suitable graph and determine total mass strictly using the slope of the graph.



$(m_2 - m_1)$ (in g)	time (t) (in s)
10.0	8.35
20.0	5.03
30.0	3.95
40.0	3.40
50.0	2.95

Sol. $a = \dfrac{(m_2 - m_1)g}{(m_2 + m_1)}$

$\therefore x = \dfrac{1}{2}\,at^2$

$\therefore t = \sqrt{\dfrac{2x(m_1 + m_2)}{(m_2 - m_1)g}} = \sqrt{\dfrac{2 \times 1}{g}\dfrac{(m_1 + m_2)}{(m_2 - m_1)}}$

Squaring ; $(m_2 - m_1) = \dfrac{2}{g}\dfrac{(m_1 + m_2)}{t^2}$

$y = \dfrac{2}{g}\dfrac{M}{t^2}$

$\dfrac{dy}{dt} = \dfrac{2}{g} \times \left(-\dfrac{2}{t^3}\right) M$

At around t = 5.0 s

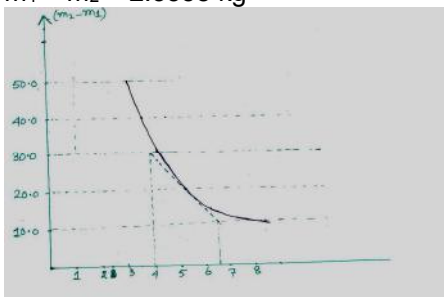
$\dfrac{dy}{dt}$ from graph $= \dfrac{30 - 10}{6.55 - 3.95}$

$= -\dfrac{20}{2.6} = -7.69$

$\therefore -\dfrac{200}{26} = \dfrac{2}{9.8}\left(-\dfrac{2}{5^8}\right) M$

$\therefore$ M = 2355.8 g

$m_1 + m_2 = 2.3558$ kg



29. **(7 marks)** Fossil fuels are used in car engines. These fuels, when burnt, emit different gases, which are responsible for air pollution.

A catalytic converter is an amazingly simple device that is highly effective at reducing harmful emissions produced by a car engine.

Modern catalytic converters are constructed from a mixture of metals. One metal serves as a catalyst for oxidation and other serves as catalyst for reduction reaction. A certain heat resistant ceramic material is thus coated with catalyst Pt-Pd/Rh.

In this catalytic converter, upto 90% of carbon monoxide from the exhaust of a car engine is oxidized to carbon dioxide, while NO and NO_2 are reduced to N_2.

Note: The exhaust of a car engine also includes small quantities of unused organic hydrocar- bons, which are also oxidized to carbon dioxide in the catalytic converter. However, for this problem, we will ignore the oxidation of hydrocarbons.

For a certain amount of fuel, the amount of carbon dioxide emitted from a car engine, without a catalytic converter, was found to be 110g. The same car engine, when fitted with a catalytic converter, emitted 132g of carbon dioxide, for the same amount of fuel.

(a) Calculate the mass of carbon monoxide emitted by the engine, without the catalytic converter, for that amount of fuel.

(b) Arnav travelled from Jodhpur to Bikaner by car, a distance of 256 km. Fuel efficiency of the car is 16 km/L. Burning one litre of the fuel produces 2.3 kg of carbon dioxide in the engine of the car. The same catalytic converter (as described above) is fitted to the car engine. Find the mass of carbon dioxide emitted by the Arnav's car during the travel.

(c) How many moles of carbon dioxide does this mass correspond to?

(d) How much mass of CO produced in this journey remains unconverted?

Sol.

(a) CO_2 produced without catalytic converter = 110 g.
CO_2 produed with catalytic converter = 132 g.
Extra CO_2 produced from CO = 132 – 110 = 22 g.
To produce 22 g CO_2, Amount of CO required
Will be $\frac{1}{2}$ mol means $\frac{1}{2} \times 28 = 14$ g.

$\because$ $2CO + O_2 \longrightarrow 2CO_2$

$\frac{1}{2}$ mol 22 g. = $\frac{1}{2}$ mol

$= \frac{1}{2} \times 28$

$= 14$ g.

Above amount of CO is 90% of original amount of CO emitted by the engine without the catalytic converter

So original amount will be $\frac{90}{100} \times x = 14$

$x = \frac{140}{9} = 15.55$ g.

(b) Jodhapur to Bikaner = 256 km
Efficiency = 16 km/L

Total fuel consumed during journey = $\frac{256}{16} = 16$ L

From 1 L fuel = 2.3 Kg CO_2 produce.
$\therefore$ from 16 L fuel amount of CO_2 produce.
Will be $= 2.3 \times 16$
$= 36.8$ kg
$= 36800$ g.

(c) Mole of CO_2 produced = $\frac{36800}{44} = 836.36$ mol.

(d) according to part (A)
If 132 g CO_2 produced with converter the unconverted amount of CO will be = 1.55 g
If 36.8 Kg CO_2 produced with converter the unconverted amount of CO will be
$= \frac{1.55}{132} \times 36.8$ = 0.432 Kg

30. **(16 marks)** The year 2019 was proclaimed by UNESCO as the International Year of the periodic Table (IYPT 2019), marking the 150th anniversary of the Mendeleev periodic table, which is an iconic representation and a vital tool to all who learn and work in science. In this question, some elements have had their symbols replaced by greek letters α, β, γ, etc., but not in order. All such elements in this question have atomic number of 20 or less. In addition, two more elements in the periodic table have been assigned codes X and Q.
Use the information about their properties, as given below, to assign each element to its correct greek / roman alphabet code.

(a) Elements α, β and γ are unreactive monatomic gases. β has the smallest atomic radius of the three, and has a higher boiling point than γ.
Identify elements α, β and γ.

The elements δ, $\in$, Ω, ψ ,θ, X and Q exist as diatomic molecules (i.e. δ_2, $\in_2$, Ω_2, ψ_2, θ_2, X_2 and Q_2). We also know that, at room temperature, X_2 is a liquid and Q_2 is a solid the other five are gases.

(b) Identify element X and Q.
ψ_2 forms compounds with each of the other six diatomic elements. Compounds of ψ with δ, and $\in_1$ and X result in diatomic gases that react with the liquid $\psi_2\theta$ to form acidic solutions.

(c) Identify elements ψ and θ. Also write a balanced chemical reaction to show how they combine with each other.

(d) δ has the highest electronegativity of these elements. The reaction between Ω_2 and ψ_2 is of immense industrial importance, the product being a gas that reacts with liquid $\psi_2\theta$ to form a basic solution. Identify elements δ, $\in$ and Ω and write balanced chemical reactions of the processes described here.

The ideal gas law is an equation to explain the behaviour of many gases under different conditions. The ideal gas equation can be written as PV = nRT where P is the pressure of the ideal gas, V is the volume of the ideal gas, n is the amount of ideal gas measured in terms of moles R is the universal gas constant, T is the temperature of the ideal gas in Kelvin.
We now consider elements κ, λ , μ and ν, which are metals that react vigorously with liquid $\psi_2\theta$ to produce ψ_2 and a basic solution.

(e) 1 g of element λ reacts with excess $\psi_2\theta$ to produce 0.3080 L of ψ_2 at 20°C and pressure of 1 atm. (Assume that ψ_2 behaves as an ideal gas under the given conditions.) Write possible balanced chemical reaction(s), calculate possible atomic mass(es) of element λ and deduce the name of this element.

(f) κ is more reactive than ν. The stable ions formed from λ and μ in this reaction have the same electron configuration. Identify elements κ, μ, ν.

(g) Elements ξ, σ and ϕ are also metals. They do not react with cold $\psi_2\theta$ but do react with θ_2 to form $\xi\theta$ $\sigma_2\theta_3$ and $\phi\theta$ respectively. Out of these, $\phi\theta$ contains the largest percentage of θ by mass. Identify the elements ξ, σ, ϕ and write these balanced chemical reactions.

Sol.

(a)

He,	Ne,	Ar
↓	↓	↓
β	γ	α

(b) $X_2 \rightarrow Br_2$ and $Q_2 \rightarrow I_2$

(c) $\psi_2 \rightarrow H_2$ and $\theta_2 \rightarrow O_2$
$2H_2 + O_2 \rightarrow 2H_2O$

(d) $\delta_2 \rightarrow F_2$, $\varepsilon_2 \rightarrow Cl_2$, $\Omega_2 \rightarrow N_2$
$N_2 + 3H_2 \rightarrow 2NH_3$
$NH_3 + H_2O \rightarrow NH_4OH$

(e) $\kappa, \lambda, \mu, \nu$

$2\lambda + 2H_2O \rightarrow 2\lambda OH + H_2$

$\frac{1}{M_\lambda}$ g 0.308L

$\Rightarrow$ PV = nRT $\Rightarrow$ $n = \frac{1\times 0.308}{0.0821\times 293.15} = \frac{0.308}{24.067615} = 0.01279$

$\Rightarrow$ $\frac{1}{M_\lambda} = 2 \times 0.01279$ $M\lambda = 39.07$

$\lambda \rightarrow K$ (Potassium)

$2K + 2H_2O \rightarrow 2KOH + H_2$

(f) $\mu \rightarrow Ca$

As per reactivity with water $\kappa \rightarrow Na$, $\nu \rightarrow Li$

(g) $\varepsilon \rightarrow Mg$

$2Mg + O_2 \rightarrow 2MgO$

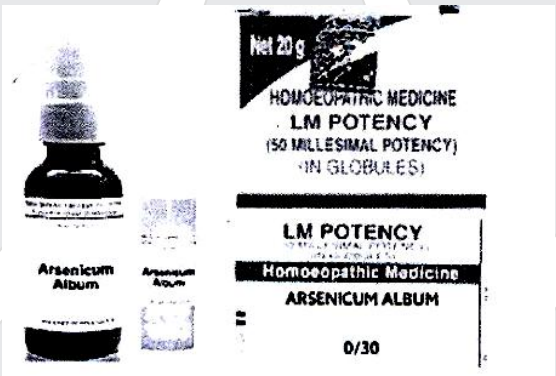
$\sigma \rightarrow Al$

$4Al + 3O_2 \rightarrow 2Al_2O_3$

$\phi \rightarrow Be$

$2Be + O_2 \rightarrow 2BeO$

31. **(7 marks)** The term pseudo-science refers to the ideas which claim to be scientific, but don't stand the scrutiny of modern science. Although many such claims have been clearly shown to be Un-scientific through detailed studies, they continue to fool non-experts by using scientific sounding arguments.



The pseudo-science of homeopathy began over two hundred years ago, long before modern medicine. The main claim in homeopathy is that the medicines become increasingly potent the more they are diluted. Let us do a series of calculations to estimate the amount of supposed medicinal molecules in a typical homeopathic solution.

Homeopaths recommend a diluted solution of arsenic oxide (As_2O_3) as a treatment for digestive disorders and anxiety. In their vocabulary, it is called by its Latin name Arsenicum album (white arsenic). The oxide is prepared industrially by roasting arsenic containing ores, such as arsenopyrite (FeAsS), in air. The other products formed are Iron(III) oxide and sulphur dioxide.

(a) Write the balanced chemical reaction for the preparation of As_2O_3 from FeAsS.

(b) As_2O_3 is moderately soluble in water. When dissolved in water, the oxide reacts to form Arsenous acid (H_3AsO_3). Write a balanced chemical equation for the formation of Arsenous acid from As_2O_3.

(c) One litre of a saturated solution of As_2O_3 at 25°C contains 20.6g of As_2O_3. Calculate the concentration of the Arsenous acid in mol/L in the saturated solution.

In homeopathy, a 'decimal-scale' is often used to specify the dilution of a given sample: D1 (sometimes labelled 1X) means the sample has been diluted 1 part in 10. D2 (or 2X) means the sample has first been diluted 1 in 10, then 1 part of that solution has been further diluted 1 in 10 again to give a 1 part in 100 dilution. A D6 (or 6X) solution has repeated this process six times to give a final dilution of 1 in 10^6.

Arsenicum album is often sold as a D30 preparation. Let us assume that the initial stock solution, before dilution, was the saturated solution containing 20.6g/L, of As_2O_3.

(d) Calculate the mass (in g) of As_2O_3 present in 100 mL glass bottle of the D30 Arsenicum album.

(e) How many such bottles (in millions, 1 million = 10^6) of the supposed medicine should one drink to be sure that at least one atom of arsenic has entered one's body?

(f) Total volume of water on the Earth is estimated to be about 1.4×10^9 km^3. If our stock solution at the start is 1L of saturated solution of As_2O_3, what is the maximum dilution of the entire stock solution one can achieve by utilizing all this water?
Note : In reality, more than 97% of water on the earth is salt water. However, for this calculation, you may assume that even this water can be desalinated and be made available for dilution.

Sol. **(a)** $2FeAsS + 5O_2 \rightarrow As_2O_3 + Fe_2O_3 + SO_2$

(b) $As_2O_3 + 3H_2O \rightarrow 2H_3AsO_3$

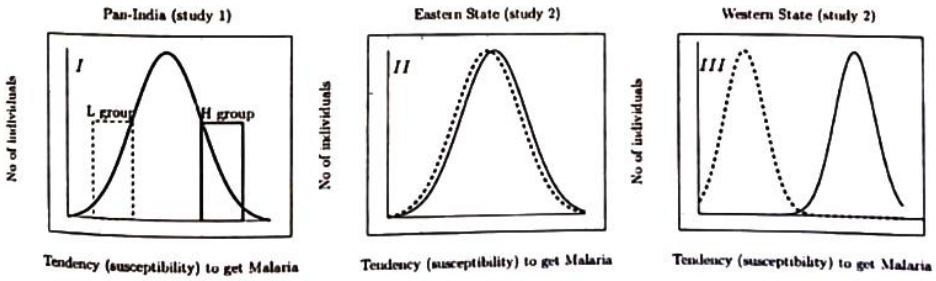
(c) concentration of $H_3AsO_3 = 2 \times \frac{20.6}{198} = 0.208 \text{ mol / L}$

(d) D30 means 1 L to 10^{30} L
10^{33} mL will have = 20.6 g
1 mL will have = $\frac{20.6}{10^{33}}$
100 mL will have = $\frac{20.6}{10^{33}} \times 100 = 2.06 \times 10^{-30}$ g

(e) Atom in one bottle = $\frac{20.6 \times 10^{-31}}{198} \times 6 \times 10^{23} \times 2 = 1.25 \times 10^{-8}$ atom
No. of bottle = $\frac{1}{1.25 \times 10^{-8}}$ = 80 million

(f) Total available vol of water = 1.4×10^{21}L
So, till D21
It can be diluted

32. **(10 marks)** The malarial parasite *(Plasmodium)* matures into an infective form inside the mosquito gut and is then transmitted to humans by mosquito bites. A survey monitored the number of malarial infections per individual in different regions of India, over a 5 year period. In this survey, certain pockets of India were deemed to be endemic, i.e. these regions showed higher incidence of the disease than average. One reason for such endemic pockets could be higher numbers of mosquito larvae in the waterlogged bodies often found in these areas.
However, we also know that people who suffer from sickle cell anemia (a genetic disorder) seem to possess some inherent resistance to the malarial infection. This is particularly evident in endemic African populations, where sickle cell anemia is also common. It is probable that sickle cell anemia was naturally selected over generations in these populations.
The results of the study, with randomly selected 100,000 individuals from all over the country, are shown in graph I. The L group (dashed box) were people with lower susceptibility to malaria, while the H group (solid box) had high susceptibility to malaria. Geographical areas (localities / towns/districts) where most of the population fell in either L group or H group were carefully identified.



After 10 years the study was repeated, for 5 more years, in two states [Eastern and Western]. I each State, the population was resampled in a randomised way from the areas identified previously as belonging to L and H groups. Each sample again consisted of 100,000 individual. Graph-II

Corresponds to the Eastern state and Graph III corresponds to the Western state. Here the dashed line shows the L group sample and the solid line shows H group Sample. Scale / axis is same for all three graphs researchers of this study want to discuss the biological basis of these differences. The following statement were considered by them for inclusion in their final report. Which of these statements may be true, based on the evidence you have ? For each statement write True/False. Each answer must be accompanied with a short (1-2 lines) justification for your claim.

(i) Graph I clearly indicates that there is no genetic basis for malarial resistance in India.

(ii) From graph I, it can be said that the chance of mosquito bites for an individual in the Indian population is totally random.

(iii) Susceptibility of individuals to malaria in the eastern state is pre-dominantly random.

(iv) In the western state, susceptibility among the H group individuals may have a genetic basis.

(v) If there is a global malarial epidemic, the H individuals in the western state have a higher chance of infection than the H individuals in the eastern state.

(vi) If there is a global malarial epidemic, the graph of malarial susceptibility of the L individuals in the western state is likely to remain unchanged.

(vii) If there is a random breakout of flu, both the L and H groups in the western state will be equally susceptible to flu.

(viii) Among the individuals who have recovered from malaria, the individuals of the H group in the western state are more likely to have scurvy than the H group individuals in the eastern state.

(ix) Some areas in the western state probably have high incidence of waterlogging.

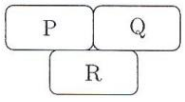
(x) Chances of finding people having sickle cell anemia will be higher in the western state than in the eastern state.

Sol. **(i)** False **(ii)** True **(iii)** True **(iv)** False **(v)** False

(vi) True **(vii)** True **(viii)** True **(ix)** True **(x)** True

33. **(7 marks)** In any plant body, movement of the water highly depends on water potential of cells, denoted by Ψ_w. The Ψ_w of pure water is zero by definition. Typically, when solutes dissolve in water, Ψ_w becomes negative.

In a cellular environment, pressure exerted by the cell wall on the inner aqueous system also contributes to ψ_w along with the dissolved solutes. Thus ψ_w is comprised of ψ_s and ψ_p(solute potential and pressure potential). Due to the difference in solute potentials of adjacent cells, water moves from high ψ_w to low ψ_w until equilibrium is attained .This movement is also restricted by the pressure potential created by the water entering from one cell to another. Therefore, solute potential and pressure potential both play a role in equilibrating ψ_w in adjacent cells.



In a hypothetical situation, plant cells P, Q and R were placed in the arrangement as shown on the right.

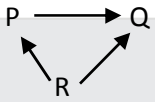
(a) Based on the values given for the cells P and R at time zero, fill the missing values in the table below.

Cell	Ψ_s (MPa)	$\Psi_p(MPa)$	$\Psi_w(MPa)$
P	-8	2	
R		2	-3

(b) At a stage when the system is at equilibrium and there is no external solute being added or pressure acting on above three cells, the water potential of the system is close to –7. What would be the ψ_w of Q at time zero?

(c) Show the water movement immediately after time zero, using an arrow diagram. Draw all possible interactions in a single diagram.

(d) At time zero, which one of these three cells is most likely to represent guard cells when the stomata needs to be opened?

Sol. **(a)** P → (–6) R → (– 5) **(b)** – 12 **(c)** 

(d) Q

34. **(5 marks)** Lions can feed on different wild animals such as zebra, wildebeest, pigs and gazelles. The efficiency of catching any particular prey will depend on a number of factors such as the net energy (E) gained by eating the prey, number of hours (s) required to search for the prey and handling time (h), i.e. the time taken to capture, kill and eat the prey. In order to maximize its overall rate of energy gain, a predator must consider the profitability (P) of the prey. It is defined as the ratio of energy gained to the time spent. Answer the following questions with a short justification (1-2 lines). Support your arguments with the data available to you.

Species	kg	h	s
Wildebeest	85	12.5	2.6
Zebra	80	11.3	4.1
Pig	37	6.8	17.8
Grant's Gazelle	27	8.0	10

(a) During the rainy season, both wildebeest and zebra are abundant. Which of them would be the preferred prey of the lion?

(b) On a regular hunt, while searching for its most preferred prey, the lion encounters a gazelle. Will it be more profitable for the lion to hunt the gazelle or leave it and continue the search?

(c) During a particular summer, all zebras and wildebeest from a jungle have migrated to another jungle. Thus, a lion is reduced to hunting either pigs or gazelles. In this situation, which would be the more profitable prey?

Sol.

(a) Wildebeest would be any easy prey because they have more productivity as compared to zebra.

(b) It will be more profitable to leave the gazelle because they are good sprinters & can run at very high speeds compared to a lion.

(c) Pigs and gazelles both are favourable because both have same productivity.

35. **(8 marks)** Any change in an environmental parameter can have a large effect on an ecosystem. Consider a pond ecosystem. Some researchers designed an experiment to study the effect of certain treatments on food webs in pond ecosystems.

Four artificial identical ponds (P,Q,R and S) were created and each was independently subjected to three treatments (W, N and F).

– W : warming of the water body

– N : addition of nutrients to the water

–F : introduction of predator fish.

Following the above treatments, each pond was studied for one of the following components.

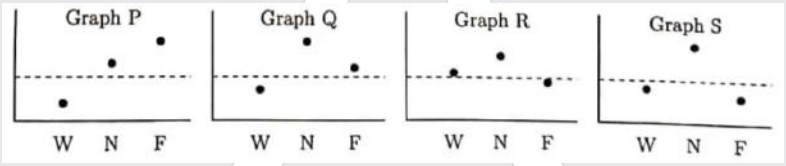
i. Number of floating plants.

ii. Number of invertebrates.

iii. Number of plants at the bottom of the pond.

iv. Number of bacterial species.

The data obtained is represented in four graphs, where the horizontal dashed line in each figure indicates the baseline data.



Match the components (i,ii,iii,iv) with the graphs (P,Q ,R and S). You MUST give a brief justification (2-3 lines) for each match.

Sol. Graph P - iii

Graph Q - i

Graph R - iv

Graph S - ii