

# (NEST-2009)

Total marks: 200

## Notes and Instructions

1. This question booklet contains 5 sections. Each section carries 50 marks.
2. First section is a general section and is compulsory.
3. Sections 2 to 5 are subject sections (mathematics, physics, chemistry and biology).  
Choose any three. That is, omit any one of the four subject sections.
4. Pocket calculator, log tables, cell phones etc. are not permitted in the examination hall.
5. Answers to the questions are to be marked in the OMR sheet provided.
6. For question booklet A, you must answer on OMR sheet A.
7. Rough work should be done on the sheets provided.
8. Retain the OMR sheet to the first sign at the end of examination.
9. Carefully read and follow the instructions in each section.
10. We urge you to read the instructions in OMR sheet.
11. Write your name, roll number and other required information with ball point pen in the appropriate boxes provided. Sign your name with ball point pen in the box provided.
12. In the remaining part of OMR sheet use HB pencil only as instructed. Make sure that the bubbles are filled properly (as shown in OMR sheet) and do not overfill.
13. Each question has four options. Fill the appropriate bubbles. Some questions (as specified in the question paper) have more than one correct choice.
14. Read and follow the instructions given on the OMR sheet.
15. Fill in the answers only when you are sure that you do not need to change the answer. As far as possible, avoid erasing the answer. In case you have to erase the answer, do so properly so that there is no black spot inside the bubble.
16. Ensure that you are filling up the bubbles corresponding to correct sections.
17. Your roll number (given on the admit card) MUST BE ENTERED CORRECTLY. If entered wrongly or not entered, the OMR sheet will not be graded.



# NATIONAL ENTRANCE SCREENING TEST (NEST-2009)

Total marks: 200

Time: 3 hours

## Notes and Instructions

1. This question booklet contains 5 sections. Each section carries 50 marks.
2. First section is a general section and it is **compulsory**.
3. Sections 2 to 5 are subject sections (mathematics, physics, chemistry and biology). **Choose any three.** That is, omit any one of the four subject sections.
4. Pocket calculators, log tables, cell phones etc are not permitted in the examination hall.
5. Answers to the questions are to be marked in the OMR sheet provided.
6. **For question booklet A, you must answer on OMR sheet A.**
7. Rough work should be done on the sheets provided.
8. Return the OMR sheet to the invigilator at the end of examination.
9. Carefully read and follow the instructions given in each section.

## Instructions for writing on OMR sheet

1. Write your name, roll number and other required information with ball point pen in the appropriate boxes provided. Sign your name with ball point pen in the box provided.
2. In the remaining part of OMR sheet use **HB pencil only as instructed. Make sure that the bubbles are filled properly** (as shown in OMR sheet).
3. Each question has four options. Fill the appropriate bubbles. Some questions (as specified in the question paper) have more than one correct choice.
4. Read and follow the instructions given on the OMR sheet.
5. Fill in the answers only when you are sure that you do not need to change the answer. As far as possible, avoid erasing the answer. In case you have to erase the answer, do so properly so that there is no black spot inside the bubble.
6. **Ensure that you are filling up the bubbles corresponding to correct sections.**
7. **Your roll number (given on the admit card) MUST BE ENTERED CORRECTLY. If entered wrongly or not entered, the OMR sheet will not be graded.**

## Section 1 General

Total marks for Section 1: 50

This section contains 22 questions.

For each question, **only one** of the 4 options is a correct answer. For questions from 1.1 to 1.6, a correct answer will earn 3 marks. For rest of the questions, each correct answer will earn 2 marks. For this section, a wrong answer or an unattempted question will earn 0 mark.

### Passage for Questions 1.1. to 1.3

Read the following passage carefully and choose the correct option from the options that follow.

According to the First Law of thermodynamics, the total energy of an isolated system is constant. If the system is not isolated but can exchange energy and/or matter with its environment, the First Law may be applied to the universe, that is, to the system plus its environment. But the First Law cannot determine the direction of spontaneous change. This is governed by the Second Law of Thermodynamics, which introduces a new variable of the system called entropy. Entropy, roughly speaking, is a measure of molecular disorder. According to the Second Law, the entropy of the universe always increases for spontaneous processes of nature. This restriction, however, says nothing about the rate of the spontaneous process.

A process is reversible if at every stage the system is in thermodynamic equilibrium and the change from one equilibrium state to another is infinitely slow. Further, a reversible process involves no dissipative effects (such as friction, viscosity, etc.). The entropy of the universe remains constant in a reversible process. Spontaneous processes are irreversible.

The First and Second Laws of Thermodynamics are never violated in nature. It is possible to express the Second Law (under certain conditions) in terms of the variables of the system alone. For example, for spontaneous processes occurring at constant temperature (T) and pressure (P), the Gibbs Free Energy (G) [which is a combination of other thermodynamic variables] of the system never increases, being constant for reversible processes. Some biological processes at constant T and P, however, are required to go in the direction of increasing G.

1.1 For **all** reversible processes,

A)  $(\Delta S)_{\text{system}} = 0$ .

B)  $(\Delta G)_{\text{system}} > 0$ .

C)  $(\Delta S)_{\text{system}} = -(\Delta S)_{\text{environment}}$ .

D)  $(\Delta S)_{\text{environment}} = 0$ .

[Here the symbols  $\Delta S$  and  $\Delta G$  mean change in entropy and Gibbs Free Energy respectively.]

1.2 Consider the process of sudden condensation of a given mass of supercooled steam into water. In this process

- A)  $(\Delta G)_{\text{system}} = 0$ .  
 B)  $(|\Delta S|)_{\text{environment}} > |(\Delta S)_{\text{system}}|$ .  
 C)  $(\Delta S)_{\text{universe}} = 0$ .  
 D)  $(\Delta S)_{\text{environment}} < 0$ .

[Here the symbol  $| |$  denotes the magnitude of the quantity inside the symbol.]

1.3 A biological process at constant T and P in which G increases is

- A) necessarily an infinitely slow reversible process.  
 B) a violation of the Second Law of Thermodynamics.  
 C) a non-spontaneous process requiring external agency.  
 D) one in which entropy of the universe decreases.

1.4 Two planes A and B inclined at  $60^\circ$  to each other intersect in a line  $l_1$ . Another plane C not parallel to  $l_1$  intersects the planes A and B in lines  $l_2$  and  $l_3$  respectively. Then

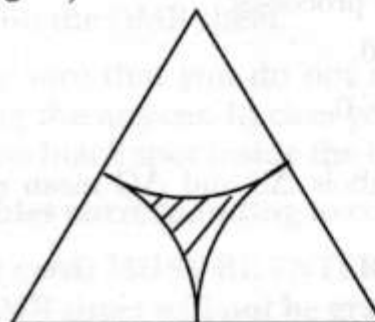
- A) A line perpendicular to plane A makes an angle of  $30^\circ$  with a line perpendicular to plane B.  
 B) the lines  $l_1$ ,  $l_2$  and  $l_3$  are concurrent.  
 C) every line in A makes an angle of  $60^\circ$  with every line in B.  
 D) the lines  $l_1$ ,  $l_2$  and  $l_3$  lie in a plane.

1.5 On a certain parliamentary committee,  $2/3$  members are men. Of the men,  $3/8$  are from Rajya Sabha. Further,  $2/5$  of the total committee members are from Rajya Sabha. What fraction of the total committee members are women from Lok Sabha?

- A)  $\frac{1}{4}$ .  
 B)  $\frac{5}{12}$ .  
 C)  $\frac{3}{20}$ .  
 D)  $\frac{11}{60}$ .

1.6 Consider an equilateral triangle of side length  $a$ . Circular arcs of radius,  $a/2$ , are drawn from each of the three vertices. The area of the region formed by the three arcs as boundaries (shown as shaded area in the figure) is

- A)  $\frac{a^2}{8} (2\sqrt{3} - \pi)$ .  
 B)  $\frac{a^2}{4} (\pi - \sqrt{3})$ .  
 C)  $\frac{a^2}{8}$ .  
 D)  $\frac{\sqrt{3}a^2}{16}$ .



For the rest of the questions in this section each correct answer will earn 2 marks.

1.7 Of the four triangular shapes (ii) to (v) ( shown in accompanying figure ), those which can be rotated to exactly resemble shape (i) are



(i)



(ii)



(iii)



(iv)



(v)

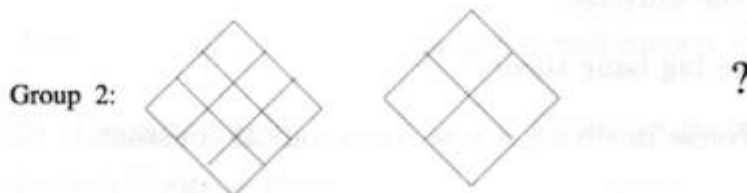
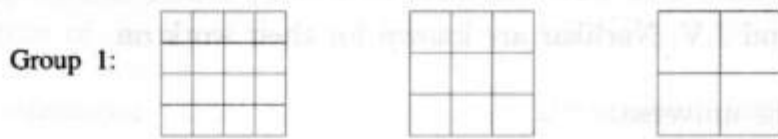
A) only(ii).

C) (iii) and (iv).

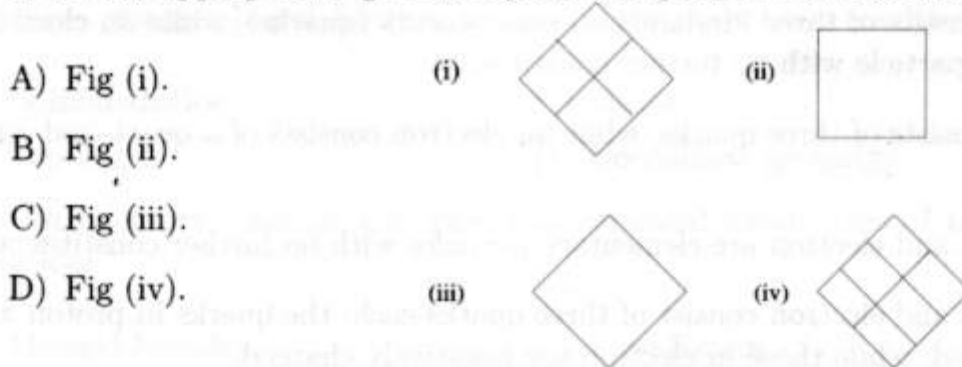
B) only(iii).

D) (ii) and (v).

1.8 Observe the figures of Group 1 and Group 2 for pattern similarity between the two groups.



The most appropriate figure to replace the question mark at the end of Group 2 is



1.9 Observe the given sequence of numbers, which has two missing numbers at the end.

20 18 17 16 14 14 11 12 ? ?

The most appropriate pair giving the missing numbers is

A) 8, 10.

C) 12, 11.

B) 13, 9.

D) 9, 10.

1.10 Observe the given sequence of numbers, which has two missing numbers at the end.

24 26 29 34 41 ? ?

The most appropriate pair giving the missing numbers is

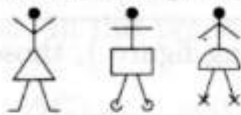
A) 50, 61.

C) 47, 59.

B) 43, 47.

D) 52, 65.

1.11 Observe the figures of Group 1, Group 2 and Group 3.



Group 1



Group 2



Group 3

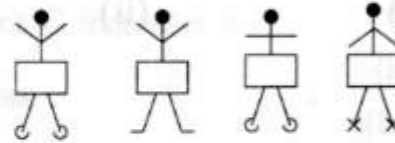
The most appropriate figure to replace the question mark at the end of Group 3 is

A) Fig(i).

B) Fig(ii).

C) Fig(iii).

D) Fig(iv).



(i)

(ii)

(iii)

(iv)

1.12 The astronomers F. Hoyle and J.V. Narlikar are known for their work on

- A) the big bang theory of the universe.
- B) the steady state theory of the universe.
- C) the inflationary phase of the big bang theory.
- D) the static model of the universe involving a new cosmological constant.

1.13 The quark model of matter is now well established. According to this model,

- A) a proton consists of three fundamental constituents (quarks), while an electron is an elementary particle with no further constituents.
- B) a proton consists of three quarks, while an electron consists of a quark and antiquark pair.
- C) both proton and electron are elementary particles with no further constituents.
- D) both proton and electron consist of three quarks each; the quarks in proton are positively charged, while those in electron are negatively charged.

1.14 In the first artificial transmutation of elements carried out by Ernest Rutherford in 1919,

- A)  $^{235}\text{U}$  nuclei were made to undergo fission by slow neutrons.
- B) neutrons were bombarded on carbon nuclei to produce radioactive  $^{14}\text{C}$ .
- C) two tritium nuclei were made to undergo fusion resulting in  $^4\text{He}$ .
- D)  $\alpha$  particles were bombarded on nitrogen nuclei producing oxygen nuclei and protons.



1.22 Radon, discovered in 1900, is

- A) a high power beam of radiation.      C) a medium wavelength radio source.  
B) a compound of radium.                  D) an inert gas.

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## Section 2 Mathematics

Total marks for Section 2: 50

*This Section contains 14 questions.*

*For questions 2.1 to 2.10, only one of the 4 options is the correct answer. A correct answer will earn 3 marks, a wrong answer will earn (-1) mark, and an unattempted question will earn 0 mark.*

2.1 Which of the following curves in the x-y plane cuts every straight line in the plane?

(I)  $x = t, y = t^2$ ; (II)  $x = t, y = t^3$ ; (III)  $x = t^2, y = t^3$ ; (IV)  $x = t^3, y = t^5$ .

- A) (I) and (III) only.                          C) (III) and (IV) only.  
B) (II) and (IV) only.                        D) all the four curves.

2.2 Let  $X = \{1, 2, 3, \dots, 9\}$  and  $A = \{3, 5, 8, 9\}$ . The number of subsets B of X which satisfy the condition  $A \setminus B = \{3, 8\}$  is

- A) zero.    C)  $2^5$ .  
B) one.    D)  $2^7$ .

2.3 A fair die is thrown successively twice and the sum of the two numbers  $s$  that show up is noted. For any subset  $T$  of  $\{2, 3, 4, \dots, 12\}$ , let  $P(T)$  denote the probability that  $s \in T$ . The smallest possible size (cardinality) of  $T$  such that  $P(T) \geq \frac{2}{3}$  is

- A) 4.    C) 6.  
B) 5.    D) 7.

2.4 A spherical ice ball is melting in such a way that its radius is decreasing at a constant rate. What should be the radius  $R$  of the ball so that the rate of decrease of its volume is numerically equal to the rate of decrease in its surface area?

- A)  $R = 2$ .                                        C)  $R = 4\pi$ .  
B)  $R = 2\pi$ .                                    D)  $R$  cannot be determined with the help of the data.

2.5 A circle touches a parabola at two distinct points  $P$  and  $Q$ . The distance between the center of the circle and the midpoint of the chord  $PQ$

- A) is a variable quantity that depends on the radius of the circle.  
B) is a constant and equals the semilatus rectum of the parabola.  
C) is a constant and equals the latus rectum of the parabola.  
D) equals  $\frac{1}{2}PQ$ .



2.6 Let  $ABCD$  be a trapezium in which  $AB$  is parallel to  $CD$ . Further  $AC$  and  $BD$  intersect at  $O$ . If the area of the triangle  $COD$  is  $10 \text{ cm}^2$ , area of the triangle  $AOB$  is  $40 \text{ cm}^2$  and  $T$  denotes the area of the trapezium  $ABCD$ , then

- A)  $T$  cannot be calculated as the data are insufficient.
- B)  $T$  can be calculated but it will have two distinct positive real values.
- C)  $T$  equals  $70 \text{ cm}^2$ .
- D)  $T$  equals  $90 \text{ cm}^2$ .

2.7 Suppose  $f(x) = -x^2 + bx + 1$  and  $g(x) = x^2 + 2x + c$  are such that  $\max f(x) \leq \min g(x)$  as  $x$  varies over the set of all real numbers. The least possible value of  $c$  is

- A) 0.
- B) 1.
- C) 2.
- D)  $\sqrt{5}$ .

2.8 Suppose the system of equations

$$\begin{aligned} ax + y + z &= 0, \\ x + ay + z &= 0, \\ x + y + az &= 0, \end{aligned}$$

has infinitely many solutions. The set of values of  $a$  for this to happen is

- A)  $\{1, -1\}$ .
- B)  $\{-1, 2\}$ .
- C)  $\{2, -2\}$ .
- D)  $\{1, -2\}$ .

2.9 The limit of the expression  $\lim_{x \rightarrow 0} \frac{\sin(x^2\pi/2)}{(\sin(x\pi/2))^2}$  is

- A) 0.
- B) 1.
- C)  $\frac{2}{\pi}$ .
- D)  $\frac{\pi}{2}$ .

2.10 Consider the function  $f : \mathbb{R} \rightarrow \mathbb{R}$  defined by

$$f(x) = \begin{cases} e^{3x} & \text{for } x \leq 0, \\ \frac{3}{2}e^{2x} - \frac{1}{2} & \text{for } x > 0. \end{cases}$$

Then  $f(x)$  is

- A) not continuous at 0.
- B) continuous at 0, but not differentiable there.
- C) differentiable at 0, but not twice differentiable there.
- D) twice differentiable at 0.

For questions 2.11 to 2.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

2.11 Consider the function  $f : \mathbb{R} \rightarrow \mathbb{R}$ ,  $f(x) = x + \sin x$ ,  $x \in \mathbb{R}$ .

- A) The function is strictly increasing at every point on  $\mathbb{R}$  except at  $x$  equal to an odd multiple of  $\pi$  where the derivative of  $f$  is zero and where the function  $f$  is not strictly increasing.
- B) The function is bounded in every bounded interval but unbounded on whole real line.
- C) The graph of the function  $y = f(x)$  lies in the first and third quadrants only.
- D) The graph of the function  $y = f(x)$  cuts the line  $y = x$  at infinitely many points.

2.12 A circular table is placed so that it touches two perpendicular walls. A point on the edge of the table is  $a$  cm away from one wall and  $b$  cm away from the other. It is required to find out all possible values of the radius  $r$  of the table. Choose the correct statement(s).

- A) The data is insufficient to find any possible value of the radius.
- B)  $r$  can be found out for any positive real values of  $a$  and  $b$ .
- C) There will always be two distinct positive values of  $r$ .
- D) If  $r$  exists, then  $\frac{9}{16}\sqrt{ab} < r < (\sqrt{a} + \sqrt{b})^2$ .

2.13 Let  $I(m, n) = \int_0^1 x^m(1-x)^n dx$ , for all non-negative integers  $m, n$ . Then

- A)  $I(m, n) < 1$  for all  $(m, n) \neq (0, 0)$ .
- B)  $I(m, n) < I(m+1, n-1)$  for all  $m \geq 0$  and  $n \geq 1$ .
- C)  $I(2, 1) = \frac{1}{12}$ .
- D)  $I(m, n)$  is a decreasing function of  $m$ .

2.14 Let a binary operation  $*$  be defined on the set  $\mathbb{C}$  of complex numbers by  $z * w = z\bar{w}$  for all  $z, w$  in  $\mathbb{C}$ . Then

- A) the operation  $*$  is associative on  $\mathbb{C}$ .
- B) given any  $z$  in  $\mathbb{C}$ ,  $z \neq 0$ , the equation  $z * w = 1$  is uniquely solvable for  $w$  in  $\mathbb{C}$ .
- C)  $\sqrt{z * z} + \sqrt{w * w} \geq \sqrt{(z + w) * (z + w)}$ .
- D)  $2(z * z + w * w) = (z + w) * (z + w) + (z - w) * (z - w)$ .

## Section 3 Physics

Total marks for Section 3: 50

This section contains 14 questions.

For questions 3.1 to 3.10, only one of the 4 options is the correct answer. A correct answer will earn 3 marks, a wrong answer will earn (-1) mark, and an unattempted question will earn 0 mark.

3.1 A physical quantity  $A(x)$  is expected to behave, according to theory, as  $A(x) = b + cx^n$ , where  $b, c, n$  are unknown positive constants. Measurements are made for  $A(x)$  for a number of values of  $x$ , including  $x = 0$ . The best way to proceed to verify the relation and to determine  $n$  and  $c$  is

- A) to find  $[A(x) - A(0)]$  for each measurement. Plot  $\ln[A(x) - A(0)]$  vs  $\ln x$  and fit it to a straight line. Slope of the line will give  $n$  and intercept will give  $\ln c$ .
- B) to plot  $A(x)$  vs  $x^n$  for various values of  $n$  till we get a straight line graph. Then the slope of the line gives  $c$ .
- C) to plot  $A(x)$  vs  $x$ . Employ the relation  $c = \frac{A(x_1) - A(x_2)}{x_1^n - x_2^n}$  for some  $n$ . Take the average value of  $c$ .
- D) to plot  $\ln A(x)$  vs  $\ln x$ . Slope will give  $n$ .

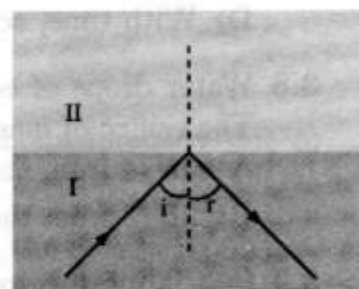
3.2 Consider two situations: (a) A capacitor of capacitance  $C$  is charged by a battery of voltage  $V$ , and then the battery is disconnected. (b) The same capacitor is charged by the same battery which, however, is kept connected. Next, in both cases, a thin dielectric slab is inserted between the capacitor plates. (Earlier there was only air). Let  $U_a$  and  $U_b$  denote the electrostatic energies in the two situations. Which of the following is true?

- A) Both  $U_a$  and  $U_b$  decrease.
- B) Both  $U_a$  and  $U_b$  increase.
- C)  $U_a$  increases while  $U_b$  decreases.
- D)  $U_b$  increases while  $U_a$  decreases.

3.3 An unpolarised monochromatic beam of light is incident on a planar interface of two media of refractive index  $n_I$  and  $n_{II}$  respectively, at an angle of incidence  $i$ . It is found that the reflected beam is completely polarised.

From this, we can conclude that

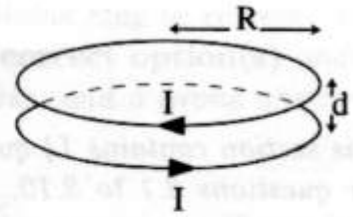
- A)  $n_I > n_{II}$  and  $i > 45^\circ$ .
- B)  $n_{II} > n_I$  and  $i = \sin^{-1}(n_I/n_{II})$ .
- C)  $i = \tan^{-1}(n_I/n_{II})$ .
- D)  $i = \tan^{-1}(n_{II}/n_I)$ .



3.4 A radioactive source, having a half-life of five minutes, was found to have a counting rate of 12000 counts/sec at a certain point in time. Fifteen minutes after this observation, the counting rate is

- A) 1500 counts/sec.
- B) 4000 counts/sec.
- C) 6000 counts/sec.
- D) 750 counts/sec.

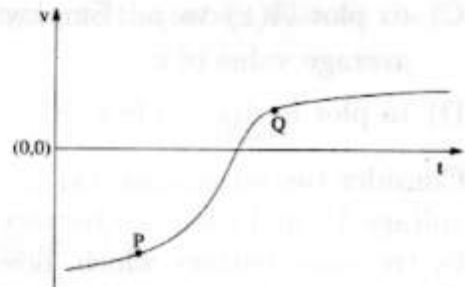
- 3.5 Two identical circular current carrying coils 1 and 2, each of radius  $R$  are placed adjacently a distance  $d$  apart ( $d \ll R$ ). They carry equal currents  $I$  in opposite sense. Let  $L_1$ ,  $L_2$ ,  $M_{12}$ , and  $M_{21}$  denote the self and mutual inductances.



Which of the following is at least approximately true?

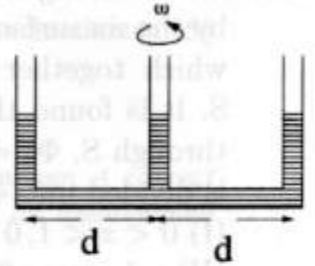
- A)  $L_1 = -L_2$ .  
 B)  $M_{12} = -M_{21}$ .  
 C)  $|L_1| = |M_{21}|$ .  
 D)  $M_{21} > L_1$ .
- 3.6 A capacitor  $C$  is charged by a constant voltage source. Let  $R$  be the net resistance in the charging circuit. As  $C$  charges, there is a Joule heating loss due to  $R$ .
- A) If  $R$  is small, current  $I(t)$  in the circuit is large, leading to a large Joule heating loss.  
 B) If  $R$  is large, the charging takes longer which increases the net Joule heating loss.  
 C) Joule heating loss is over infinite period, and is therefore infinite.  
 D) Net Joule heating loss is independent of  $R$ .

- 3.7 Following is a graph of velocity ( $v$ ) versus time ( $t$ ) for a particle. Choose the correct statement among the following statements.



- A) Speed at P is more than at Q and displacement at P is less than at Q.  
 B) Acceleration at Q is less than that at P and displacement at Q is more than at P.  
 C) With time, acceleration at P is increasing while displacement is decreasing.  
 D) With time, acceleration at Q is increasing while displacement is also increasing.
- 3.8 Water drops of equal size are dripping at a constant rate from a tap at height  $H$ . The centre of mass of the column of drops at a given instant is located at a height of
- A)  $3H/4$  from the ground.  
 B)  $2H/3$  from the ground.  
 C)  $H/2$  from the ground.  
 D)  $H/3$  from the ground.
- 3.9 In a laboratory projectiles of mass  $m_1$  collide with a target of mass  $m_2$  at rest. It is observed that there are projectiles hurled at large scattering angles ( $> 150^\circ$ ). For this to happen
- A) the impact parameter of  $m_1$  must be large and  $m_1 < m_2$ .  
 B) the impact parameter of  $m_1$  must be small and  $m_1 < m_2$ .  
 C) the impact parameter of  $m_1$  must be large and  $m_1 > m_2$ .  
 D) the impact parameter of  $m_1$  must be small and  $m_1 > m_2$ .

- 3.10 A thin uniform tube in the shape of "W" containing a liquid is rotated about the central vertical column with constant angular speed  $\omega$ . If the separation between two adjacent columns is  $d$ , then



- A) the liquid in the central column rises a height  $(d\omega)^2/g$  above that of the outer columns.  
 B) the liquid in the outer columns rises a height  $(d\omega)^2/g$  above that of the central column.  
 C) the liquid in the outer columns rises a height  $(d\omega)^2/2g$  above that of the central column.  
 D) the liquid in the central column rises a height  $2(d\omega)^2/g$  above that of the outer columns.

For questions 3.11 to 3.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

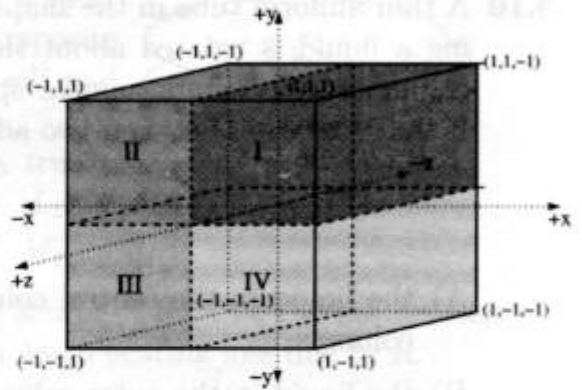
- 3.11 Two sinusoidal waves, whose displacements are given by  $y_1 = A \sin(2\pi\nu_1 t - k_1 x)$  and  $y_2 = A \sin(2\pi\nu_2 t - k_2 x)$ , are simultaneously present in a medium. Given that  $\nu_1 = 100$  Hz,  $\nu_2 = 200$  Hz,  $k_1 = \frac{2\pi}{3}$  m<sup>-1</sup> and  $k_2 = \frac{4\pi}{3}$  m<sup>-1</sup>, an observer located at the origin finds
- A) an intensity maximum at  $t = 0$  and an intensity minimum at  $t = \frac{1}{300}$  s at the origin.  
 B) intensity minima at  $t = \frac{1}{300}$  s and at  $t = \frac{1}{200}$  s at the origin.  
 C) the speed of the waves in the medium is 300 m s<sup>-1</sup>.  
 D) the maximum intensity at the origin is 2 times the maximum intensity due to each wave in the absence of the other.
- 3.12 In an  $\alpha$ -decay of a nucleus of  $A = 200$  at rest in the laboratory, the  $Q$ -value is 5 MeV. Choose the correct statement(s).
- A) The de Broglie wavelengths of the emitted  $\alpha$  particle and of the recoil nucleus are equal.  
 B) The kinetic energy of the  $\alpha$  particle and the recoil nucleus (as seen in the laboratory) are nearly equal.  
 C) The kinetic energy of the  $\alpha$  particle is approximately 4.9 MeV.  
 D) The de Broglie wavelength of the  $\alpha$  particle is approximately 1 Å.

**3.13** A cubical region (sides of 2 units) is bounded by the six surfaces:  $x = \pm 1, y = \pm 1, z = \pm 1$ , which together constitute a closed surface  $S$ . It is found that the net electrostatic flux through  $S$ ,  $\Phi_S = 0$ . The volume of the cube is divided into 4 equal regions:

- (I)  $0 < x < 1, 0 < y < 1, -1 < z < 1$ ,
- (II)  $-1 < x < 0, 0 < y < 1, -1 < z < 1$ ,
- (III)  $-1 < x < 0, -1 < y < 0, -1 < z < 1$ ,
- and
- (IV)  $0 < x < 1, -1 < y < 0, -1 < z < 1$ .

It is found that  $|\Phi_I| \neq |\Phi_{II}|$ . We can conclude that

- A) there are no charges anywhere in  $S$ , since  $\Phi_S = 0$ .
- B) at least one of the regions I and II have charges present.
- C) at least one of  $\Phi_{III}$  and  $\Phi_{IV}$  is non-zero.
- D)  $|\Phi_I| + |\Phi_{II}| + |\Phi_{III}| + |\Phi_{IV}| > 0$ .



**3.14** A certain diatomic gas has the same specific heats as an ideal gas but a slightly different equation of state:  $PV = R(T + \alpha T^2)$ ,  $\alpha = 0.001 \text{ K}^{-1}$ . The temperature of the gas is raised from  $T_1 = 300 \text{ K}$  to  $T_2$  at constant pressure. It is found that work done on the gas is 70% higher than what would be on an ideal gas. Choose the correct statement(s).

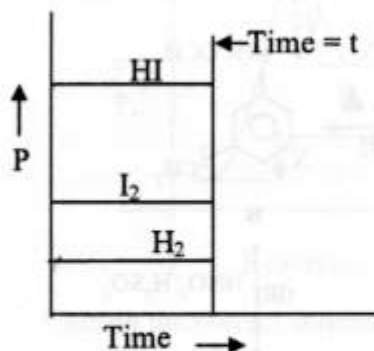
- A)  $T_2 = 400 \text{ K}$ , internal energy increases by  $250R$  per mole.
- B)  $T_2 = 400 \text{ K}$ , internal energy increases by  $350R$  per mole.
- C) Total heat absorbed in the process is  $450R$  per mole.
- D) Total heat absorbed in the process is  $520R$  per mole.



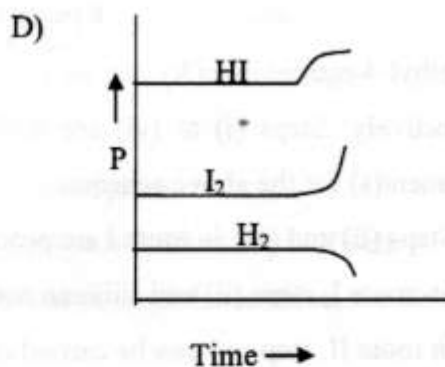
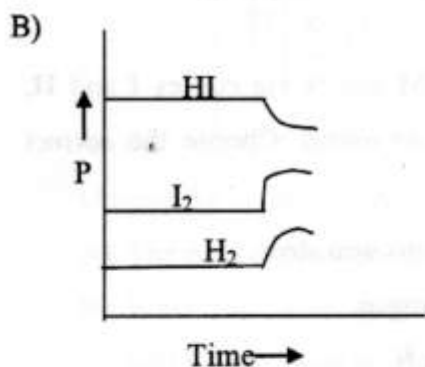
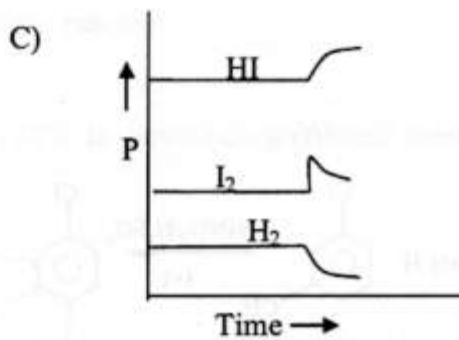
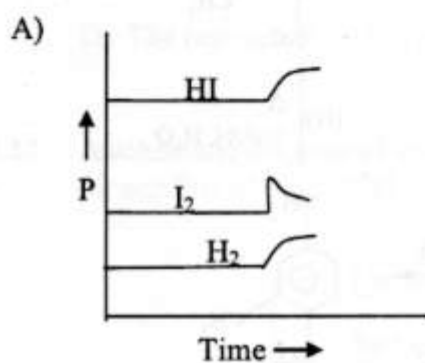
- 4.4 The molecule /ion with highest O-N-O bond angle is  
 A)  $\text{NO}_2^-$                       C)  $\text{NO}_2^+$   
 B)  $\text{NO}_3^-$                       D)  $\text{NO}_2$
- 4.5 Aluminum is extracted by electrolysis from Bauxite and this process is known as Hall-Heroult process. In this extraction, it is advantageous to use a mixture of bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) and  $\text{Na}_3\text{AlF}_6$ . The role of  $\text{Na}_3\text{AlF}_6$  in this mixture is  
 A) to increase melting point of the mixture.  
 B) to improve electrical conductivity of the cell.  
 C) to convert bauxite into aluminium fluoride.  
 D) to enrich the aluminum content of the ore.
- 4.6 The metal ion whose hydrated form will be almost colourless is  
 A)  $\text{Cu}^{2+}$                       C)  $\text{Mn}^{2+}$   
 B)  $\text{Na}^{2+}$                       D)  $\text{Co}^{2+}$
- 4.7 For an ideal gas undergoing isothermal expansion (E: internal energy, S: entropy)  
 A)  $\Delta E > 0, \Delta S > 0.$                       C)  $\Delta E = 0, \Delta S = 0.$   
 B)  $\Delta E = 0, \Delta S > 0.$                       D)  $\Delta E < 0, \Delta S > 0.$
- 4.8 The mixture of the solutions that will lead to formation of  $\text{CaF}_2$  precipitate is (solubility product of  $\text{CaF}_2 = 4 \times 10^{-11}$ )  
 A) 100 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $2.0 \times 10^{-4} \text{ M F}^-$ .  
 B) 50 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $2.0 \times 10^{-4} \text{ M F}^-$ .  
 C) 100 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 50 mL of  $1.0 \times 10^{-4} \text{ M F}^-$ .  
 D) 100 mL of  $2.0 \times 10^{-2} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $6.0 \times 10^{-3} \text{ M F}^-$ .



4.9 Consider gaseous reaction at equilibrium:  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g})$ . The following figure qualitatively indicates pressure  $P$  for these gases at equilibrium in a container.



To this equilibrium system, at time  $t$ , an extra  $\text{I}_2(\text{g})$  is added. The set of curves that appropriately indicates the response of the system to the above situation is

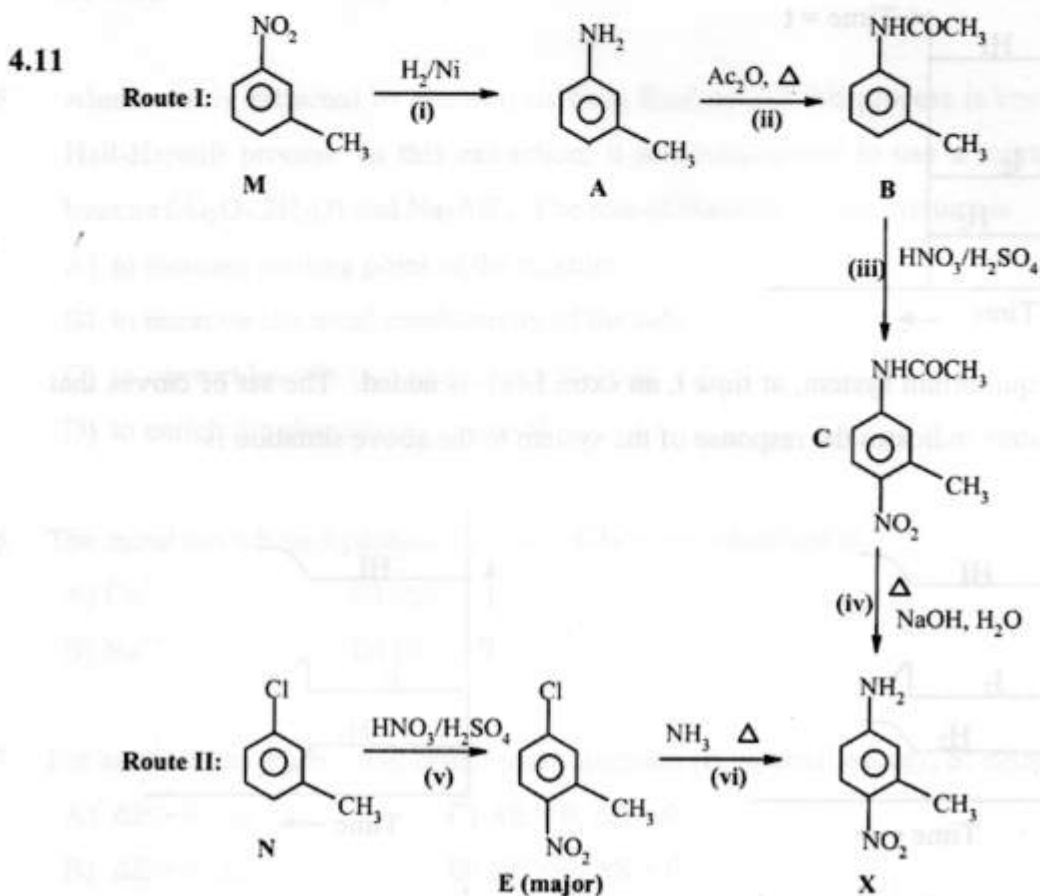


4.10 The solution that is most basic is

A)  $[\text{H}_3\text{O}^+] = 10^{-6}$       C)  $[\text{OH}^-] = 10^{-4}$

B)  $\text{pH} = 8$                       D)  $[\text{H}_3\text{O}^+] = 10^{-9}$

For questions 4.11 to 4.14, more than one of the four options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.



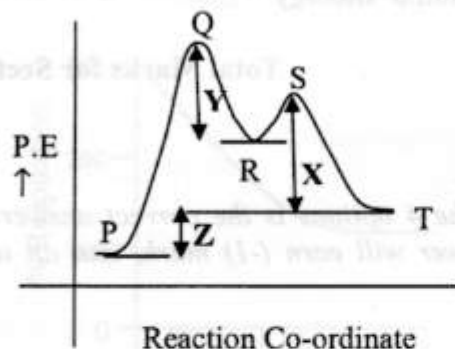
3-methyl-4-nitroaniline(X) can be prepared from M and N via routes I and II, respectively. Steps (i) to (vi) are involved in these routes. Choose the correct statement(s) for the above schemes.

- A) Steps (ii) and (iii) in route I are protection-deprotection steps.
- B) In route I, steps (ii) and (iii) can not be interchanged.
- C) In route II, step (vi) can be carried out easily on N.
- D) Nitration of M will give 2,5-dinitrotoluene.

4.12 Choose the correct statements for the series  $\text{BH}_3$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$ .

- A) Bronsted acidity increases from left to right.
- B) The central atom in each molecule can have maximum of 8 electrons in its valence shell.
- C) The pKa values decrease from right to left.
- D) Lewis acidity increases from left to right.

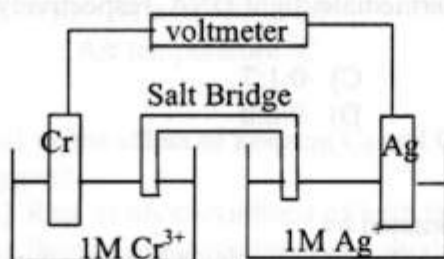
4.13 The potential energy curve for a reaction going from P to T is given below.



Choose the correct statement(s) for the above system.

- A) Conversion of  $P \rightarrow R$  is the rate determining step of the overall reaction.
- B) S indicates presence of an intermediate.
- C) Enthalpy of the reaction is given by  $Z + X$ .
- D) The reaction  $P \rightarrow T$  is an endothermic reaction.

4.14 A schematic diagram of voltaic cell at  $25^\circ\text{C}$  is shown below (Atomic mass of Cr = 52 and that of Ag = 108).

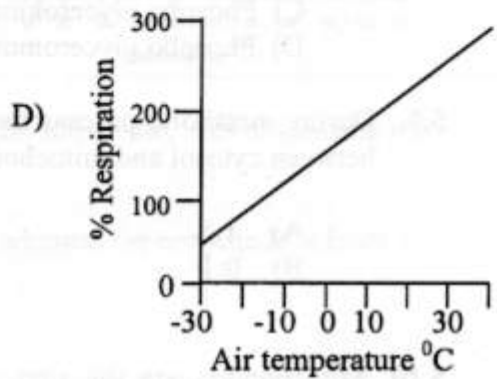
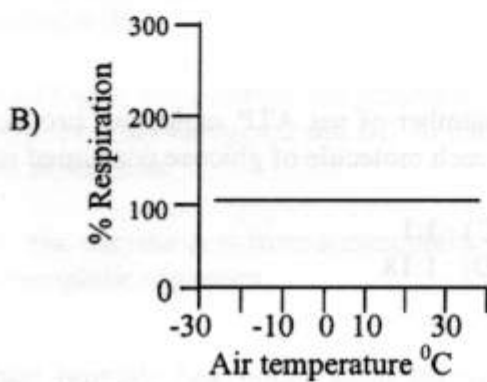
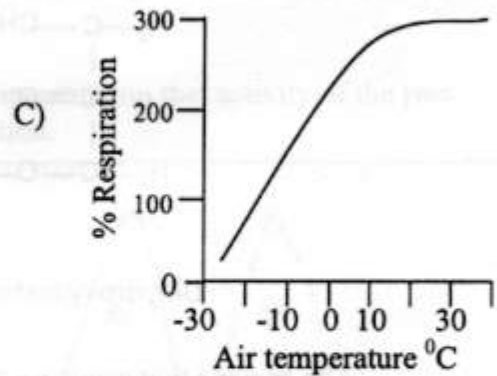
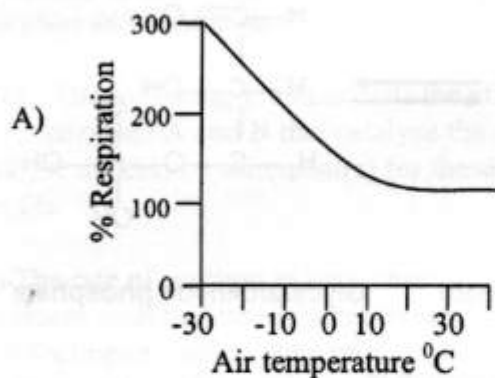


Choose the correct statement(s) for the above system.

- A) The positive ions in the solution will migrate towards Ag half cell.
- B) When two moles of electrons are passed through the solution, the Cr electrode will lose its mass by about 35 g.
- C) If accidentally solid  $\text{Na}_2\text{S}$  falls into  $\text{Ag}^+$  electrode and turbidity is observed in silver half cell, the cell potential will decrease.
- D) The silver electrode will show increase in mass.



5.5. Which of the following graphs correctly depicts the rate of respiration of a non-hibernating mammal living in cold climate?



5.6. What will be the effect of keeping  $C_3$  and  $C_4$  plants in an environment having 15% oxygen?

- (A) Rate of photosynthesis of both the plants will be reduced.
- (B) Rate of photosynthesis of only the  $C_4$  plant will increase.
- (C) Rate of photosynthesis of only the  $C_3$  plant will increase.
- (D) Rate of photosynthesis of both the plants will increase.

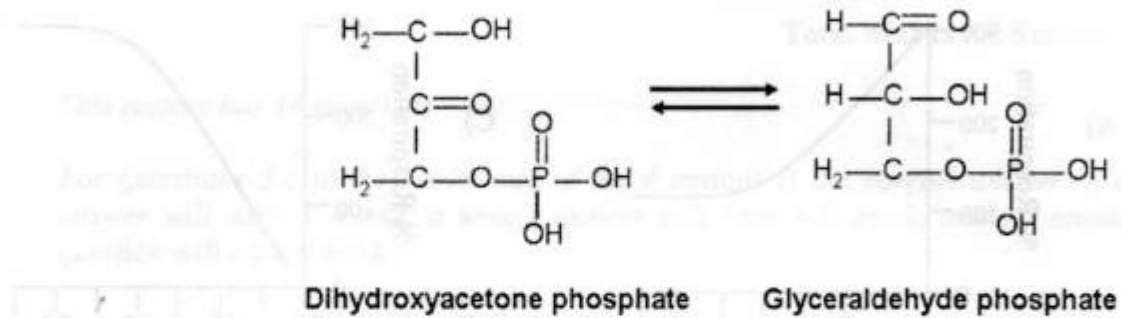
5.7. Relative amounts (mole %) of nitrogenous bases in a genomic DNA sample are as follows:

A: 24.7      G: 24.1      T: 32.7      C: 18.5

The most likely source of DNA is:

- A) virus.
- B) Bacterium.
- C) Yeast.
- D) Salmon sperm.

- 5.8. Dihydroxy acetone phosphate and glyceraldehyde -3-phosphate are reversibly interconvertible.



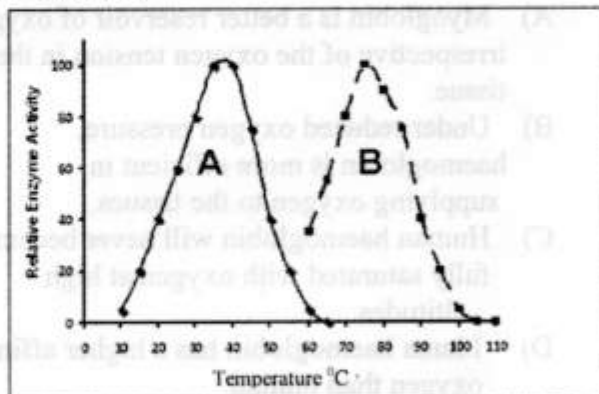
The enzyme that catalyzes the above reaction is

- A) Aldolase.  
 B) Isomerase.  
 C) Phospho glycerokinase.  
 D) Phospho glyceromutase.
- 5.9. During metabolic process the ratio of number of net ATP molecules produced between cytosol and mitochondrion for each molecule of glucose consumed is
- A) 1:8  
 B) 0:1  
 C) 1:1  
 D) 1:18
- 5.10. Mitochondria are the sites of oxidative phosphorylation and electron transport. Hence, they are known as the powerhouse of the cell. Select the correct statement about these organelles.
- A) They are present in all prokaryotic and eukaryotic organisms.  
 B) They are present only in aerobic prokaryotes and all eukaryotes.  
 C) They are present in all living cells except viruses.  
 D) They are present only in eukaryotes.

For Questions 5.11 to 5.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

5.11. The following graph depicts the effect of temperature on the activity of the two enzymes A and B that catalyze the same reaction.

Choose the correct statement(s) for these results.



A) The rate of reaction in each case increases with increase in temperature and declines at higher temperatures due to denaturation of the enzyme.

B) Both the enzymes A and B are thermolabile.

C) At higher temperature, the reactants become highly energized and fail to interact with the active site, thus decreasing the rate of reaction.

D) The enzyme A is from a mesophilic organism, whereas the enzyme B is from a thermophilic organism.

5.12. Mutations in *Neurospora* were generated and screened to find out if some amino acids were required to support their growth. Following table depicts the results of screening of three such mutants (*Mut 1*, *2*, and *3*) that mapped to three genes (genes 1, 2 and 3, respectively):

Mutant Type	Gene	Supplement			
		no arginine no ornithine no citrulline	+ ARGININE no ornithine no citrulline	no arginine + ORNITHINE no citrulline	no arginine no ornithine + CITRULLINE
<i>Mut 1</i>	<i>Gene 1</i>	no growth	GROWTH	no growth	GROWTH
<i>Mut 2</i>	<i>Gene 2</i>	no growth	GROWTH	GROWTH	GROWTH
<i>Mut 3</i>	<i>Gene 3</i>	no growth	GROWTH	no growth	no growth

Choose the correct statement(s) for the above experiment.

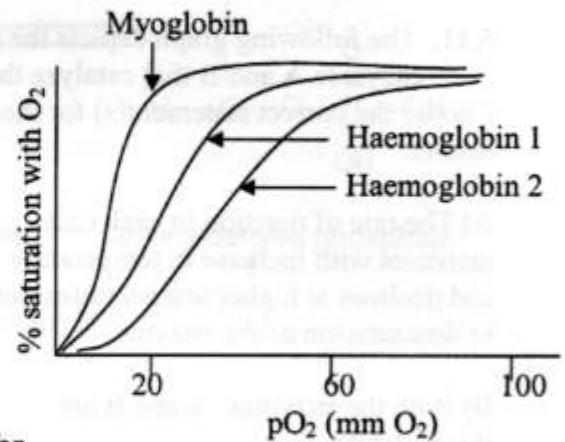
A) All the three genes code for enzymes in a pathway responsible for synthesis of arginine.

B) For the synthesis of arginine, ornithine and citrulline are the intermediates.

C) Gene 3 codes for an enzyme that catalyzes conversion of citrulline to arginine.

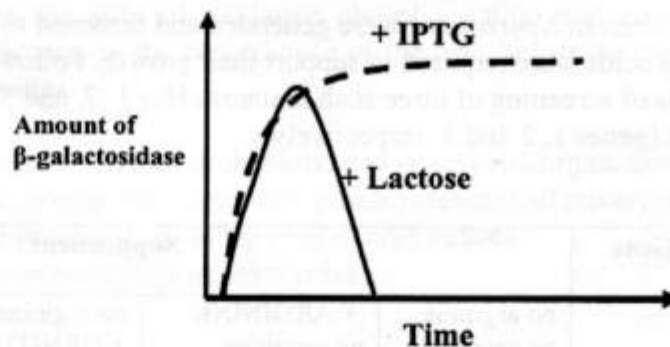
D) Gene 1 codes for an enzyme that catalyzes formation of ornithine from a precursor.

5.13. Haemoglobin and myoglobin are protein molecules that can bind to oxygen. Haemoglobin 1 in the graph is from Llama – a mammal living at high altitude and haemoglobin 2 belongs to human. Choose the correct interpretation(s) of the graph.



- A) Myoglobin is a better reservoir of oxygen irrespective of the oxygen tension in the tissue.
- B) Under reduced oxygen pressure, haemoglobin is more efficient in supplying oxygen to the tissues.
- C) Human haemoglobin will never become fully saturated with oxygen at high altitudes.
- D) Llama haemoglobin has a higher affinity for oxygen than human.

5.14. *Lac*-operon is an inducible operon that synthesizes  $\beta$ -galactosidase, an enzyme responsible for breakdown of lactose into galactose and glucose. Isopropyl thio galacto pyranoside (IPTG) is a structural analogue of lactose that also induces the *lac*-operon, but it cannot be broken down by  $\beta$ -galactosidase. The kinetics of activation of *lac*-operon by lactose and IPTG are shown below.



Choose the correct statement(s) for the above kinetics.

- A) The different kinetics could be because the IPTG has been added in very high concentration whereas lactose is added in limited quantity.
- B) Since lactose is also the substrate for  $\beta$ -galactosidase, the  $\beta$ -galactosidase that is induced degrades lactose. Consequently, the concentration of lactose decreases and hence the decline in the induction of *lac*-operon.
- C) Since IPTG is not a substrate for  $\beta$ -galactosidase, its concentration remains unaffected by the presence of enzyme. Consequently, the operon is continuously induced.
- D) Lactose binds to the repressor transiently, whereas IPTG binds permanently.

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# (NEST-2009)

## Notes and Instructions

This question booklet contains 2 sections. Each section carries 50 marks.

1. First section is a general section and is compulsory.

2. Sections 2 to 5 are subject sections (mathematics, physics, chemistry and biology). Choose any three. There is one sub-part of the first subject section.

3. Pocket calculator, log tables, cell phones etc are not permitted in the examination.

4. Answers to the questions are to be marked in the OMR sheet provided.

5. For question booklet B, you must answer on OMR sheet B.

6. Rough work should be done on the sheets provided.

7. Honour the OMR sheet in the right hand side of examination booklet A.

8. Carefully read and follow the instructions in each section.

**B**

9. In the remaining part of OMR sheet use HB pencil only as instructed. Make sure that the bubbles are filled properly as shown in OMR sheet.

10. Each question has four options. Fill the appropriate bubble. Some questions (as specified in the question paper) have more than one correct choice.

11. Read and follow the instructions given on the OMR sheet.

12. Fill in the answer only when you are sure that you do not need to change the answer. As far as possible, avoid erasing the answer. In case you have to erase the answer do so properly so that there is no black spot inside the bubble.

13. Ensure that you are filling up the bubbles corresponding to correct sections.

14. Your roll number (given on the admit card) MUST BE ENTERED CORRECTLY. If entered wrongly or not entered, the OMR sheet will not be graded.

# NATIONAL ENTRANCE SCREENING TEST (NEST-2009)

Total marks: 200

Time: 3 hours

(NEST-2009)

## Notes and Instructions

1. This question booklet contains 5 sections. Each section carries 50 marks.
2. First section is a general section and it is **compulsory**.
3. Sections 2 to 5 are subject sections (mathematics, physics, chemistry and biology). **Choose any three.** That is, omit any one of the four subject sections.
4. Pocket calculators, log tables, cell phones etc are not permitted in the examination hall.
5. Answers to the questions are to be marked in the OMR sheet provided.
6. **For question booklet B, you must answer on OMR sheet B.**
7. Rough work should be done on the sheets provided.
8. Return the OMR sheet to the invigilator at the end of examination.
9. Carefully read and follow the instructions given in each section.

## Instructions for writing on OMR sheet

1. Write your name, roll number and other required information with ball point pen in the appropriate boxes provided. Sign your name with ball point pen in the box provided.
2. In the remaining part of OMR sheet use **HB pencil only as instructed. Make sure that the bubbles are filled properly** (as shown in OMR sheet).
3. Each question has four options. Fill the appropriate bubbles. Some questions (as specified in the question paper) have more than one correct choice.
4. Read and follow the instructions given on the OMR sheet.
5. Fill in the answers only when you are sure that you do not need to change the answer. As far as possible, avoid erasing the answer. In case you have to erase the answer, do so properly so that there is no black spot inside the bubble.
6. **Ensure that you are filling up the bubbles corresponding to correct sections.**
7. **Your roll number (given on the admit card) MUST BE ENTERED CORRECTLY. If entered wrongly or not entered, the OMR sheet will not be graded.**

## Section 1 General

Total marks for Section 1: 50

This section contains 22 questions.

For each question, **only one** of the 4 options is a correct answer. For questions from 1.1 to 1.6, a correct answer will earn 3 marks. For rest of the questions, each correct answer will earn 2 marks. For this section, a wrong answer or an unattempted question will earn 0 mark.

### Passage for Questions 1.1. to 1.3

Read the following passage carefully and choose the correct option from the options that follow.

According to the First Law of thermodynamics, the total energy of an isolated system is constant. If the system is not isolated but can exchange energy and/or matter with its environment, the First Law may be applied to the universe, that is, to the system plus its environment. But the First Law cannot determine the direction of spontaneous change. This is governed by the Second Law of Thermodynamics, which introduces a new variable of the system called entropy. Entropy, roughly speaking, is a measure of molecular disorder. According to the Second Law, the entropy of the universe always increases for spontaneous processes of nature. This restriction, however, says nothing about the rate of the spontaneous process.

A process is reversible if at every stage the system is in thermodynamic equilibrium and the change from one equilibrium state to another is infinitely slow. Further, a reversible process involves no dissipative effects (such as friction, viscosity, etc.). The entropy of the universe remains constant in a reversible process. Spontaneous processes are irreversible.

The First and Second Laws of Thermodynamics are never violated in nature. It is possible to express the Second Law (under certain conditions) in terms of the variables of the system alone. For example, for spontaneous processes occurring at constant temperature (T) and pressure (P), the Gibbs Free Energy (G) [which is a combination of other thermodynamic variables] of the system never increases, being constant for reversible processes. Some biological processes at constant T and P, however, are required to go in the direction of increasing G.

1.1 For all reversible processes,

A)  $(\Delta S)_{\text{system}} = 0$ .

C)  $(\Delta S)_{\text{system}} = -(\Delta S)_{\text{environment}}$ .

B)  $(\Delta G)_{\text{system}} > 0$ .

D)  $(\Delta S)_{\text{environment}} = 0$ .

[Here the symbols  $\Delta S$  and  $\Delta G$  mean change in entropy and Gibbs Free Energy respectively.]

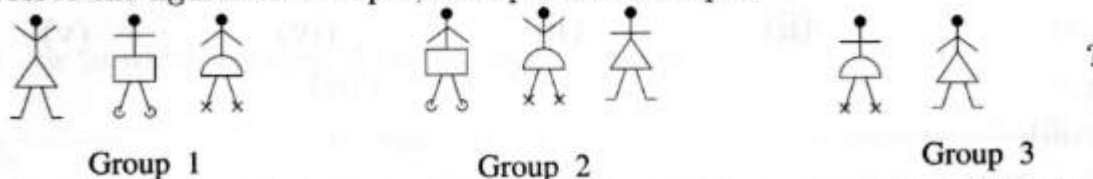




1.11 The quark model of matter is now well established. According to this model,

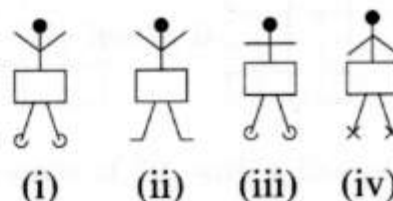
- A) both proton and electron consist of three quarks each; the quarks in proton are positively charged, while those in electron are negatively charged.
- B) a proton consists of three fundamental constituents (quarks), while an electron is an elementary particle with no further constituents.
- C) a proton consists of three quarks, while an electron consists of a quark and antiquark pair.
- D) both proton and electron are elementary particles with no further constituents.

1.12 Observe the figures of Group 1, Group 2 and Group 3.



The most appropriate figure to replace the question mark at the end of Group 3 is

- A) Fig(i).
- B) Fig(ii).
- C) Fig(iii).
- D) Fig(iv).



1.13 In the first artificial transmutation of elements carried out by Ernest Rutherford in 1919,

- A) two tritium nuclei were made to undergo fusion resulting in  ${}^4\text{He}$ .
- B)  $\alpha$  particles were bombarded on nitrogen nuclei producing oxygen nuclei and protons.
- C)  ${}^{235}\text{U}$  nuclei were made to undergo fission by slow neutrons.
- D) neutrons were bombarded on carbon nuclei to produce radioactive  ${}^{14}\text{C}$ .

1.14 The astronomers F. Hoyle and J.V. Narlikar are known for their work on

- A) the big bang theory of the universe.
- B) the static model of the universe involving a new cosmological constant.
- C) the steady state theory of the universe.
- D) the inflationary phase of the big bang theory.









For questions 2.11 to 2.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

2.11 Let a binary operation  $*$  be defined on the set  $\mathbb{C}$  of complex numbers by  $z * w = z\bar{w}$  for all  $z, w$  in  $\mathbb{C}$ . Then

- A)  $\sqrt{z * z} + \sqrt{w * w} \geq \sqrt{(z + w) * (z + w)}$ .
- B)  $2(z * z + w * w) = (z + w) * (z + w) + (z - w) * (z - w)$ .
- C) the operation  $*$  is associative on  $\mathbb{C}$ .
- D) given any  $z$  in  $\mathbb{C}$ ,  $z \neq 0$ , the equation  $z * w = 1$  is uniquely solvable for  $w$  in  $\mathbb{C}$ .

2.12 Consider the function  $f : \mathbb{R} \rightarrow \mathbb{R}$ ,  $f(x) = x + \sin x$ ,  $x \in \mathbb{R}$ .

- A) The graph of the function  $y = f(x)$  cuts the line  $y = x$  at infinitely many points.
- B) The function is strictly increasing at every point on  $\mathbb{R}$  except at  $x$  equal to an odd multiple of  $\pi$  where the derivative of  $f$  is zero and where the function  $f$  is not strictly increasing.
- C) The function is bounded in every bounded interval but unbounded on whole real line.
- D) The graph of the function  $y = f(x)$  lies in the first and third quadrants only.

2.13 Let  $I(m, n) = \int_0^1 x^m(1-x)^n dx$ , for all non-negative integers  $m, n$ . Then

- A)  $I(2, 1) = \frac{1}{12}$ .
- B)  $I(m, n) < 1$  for all  $(m, n) \neq (0, 0)$ .
- C)  $I(m, n) < I(m + 1, n - 1)$  for all  $m \geq 0$  and  $n \geq 1$ .
- D)  $I(m, n)$  is a decreasing function of  $m$ .

2.14 A circular table is placed so that it touches two perpendicular walls. A point on the edge of the table is  $a$  cm away from one wall and  $b$  cm away from the other. It is required to find out all possible values of the radius  $r$  of the table. Choose the correct statement(s).

- A) The data is insufficient to find any possible value of the radius.
- B)  $r$  can be found out for any positive real values of  $a$  and  $b$ .
- C) There will always be two distinct positive values of  $r$ .
- D) If  $r$  exists, then  $\frac{9}{16}\sqrt{ab} < r < (\sqrt{a} + \sqrt{b})^2$ .

### Section 3 Physics

**Total marks for Section 3: 50**

*This section contains 14 questions.*

*For questions 3.1 to 3.10, only one of the 4 options is the correct answer. A correct answer will earn 3 marks, a wrong answer will earn (-1) mark, and an unattempted question will earn 0 mark.*

**3.1** Consider two situations: (a) A capacitor of capacitance  $C$  is charged by a battery of voltage  $V$ , and then the battery is disconnected. (b) The same capacitor is charged by the same battery which, however, is kept connected. Next, in both cases, a thin dielectric slab is inserted between the capacitor plates. (Earlier there was only air). Let  $U_a$  and  $U_b$  denote the electrostatic energies in the two situations. Which of the following is true?

- A)  $U_a$  increases while  $U_b$  decreases.                      C) Both  $U_a$  and  $U_b$  decrease.  
 B)  $U_b$  increases while  $U_a$  decreases.                      D) Both  $U_a$  and  $U_b$  increase.

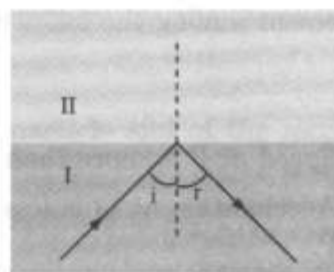
**3.2** A radioactive source, having a half-life of five minutes, was found to have a counting rate of 12000 counts/sec at a certain point in time. Fifteen minutes after this observation, the counting rate is

- A) 750 counts/sec.    C) 4000 counts/sec.  
 B) 1500 counts/sec.    D) 6000 counts/sec.

**3.3** A physical quantity  $A(x)$  is expected to behave, according to theory, as  $A(x) = b + cx^n$ , where  $b, c, n$  are unknown positive constants. Measurements are made for  $A(x)$  for a number of values of  $x$ , including  $x = 0$ . The best way to proceed to verify the relation and to determine  $n$  and  $c$  is

- A) to find  $[A(x) - A(0)]$  for each measurement. Plot  $\ln[A(x) - A(0)]$  vs  $\ln x$  and fit it to a straight line. Slope of the line will give  $n$  and intercept will give  $\ln c$ .  
 B) to plot  $A(x)$  vs  $x^n$  for various values of  $n$  till we get a straight line graph. Then the slope of the line gives  $c$ .  
 C) to plot  $A(x)$  vs  $x$ . Employ the relation  $c = \frac{A(x_1) - A(x_2)}{x_1^n - x_2^n}$  for some  $n$ . Take the average value of  $c$ .  
 D) to plot  $\ln A(x)$  vs  $\ln x$ . Slope will give  $n$ .

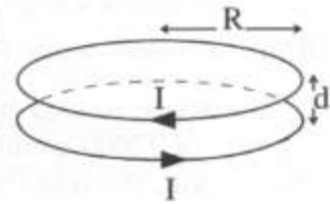
**3.4** An unpolarised monochromatic beam of light is incident on a planar interface of two media of refractive index  $n_I$  and  $n_{II}$  respectively, at an angle of incidence  $i$ . It is found that the reflected beam is completely polarised.



- From this, we can conclude that  
 A)  $n_I > n_{II}$  and  $i > 45^\circ$ .    C)  $i = \tan^{-1}(n_I/n_{II})$ .  
 B)  $n_{II} > n_I$  and  $i = \sin^{-1}(n_I/n_{II})$ .    D)  $i = \tan^{-1}(n_{II}/n_I)$ .

- 3.5 A capacitor  $C$  is charged by a constant voltage source. Let  $R$  be the net resistance in the charging circuit. As  $C$  charges, there is a Joule heating loss due to  $R$ .
- A) Joule heating loss is over infinite period, and is therefore infinite.  
 B) If  $R$  is small, current  $I(t)$  in the circuit is large, leading to a large Joule heating loss.  
 C) If  $R$  is large, the charging takes longer which increases the net Joule heating loss.  
 D) Net Joule heating loss is independent of  $R$ .
- 3.6 Water drops of equal size are dripping at a constant rate from a tap at height  $H$ . The centre of mass of the column of drops at a given instant is located at a height of
- A)  $3H/4$  from the ground.                      C)  $H/2$  from the ground.  
 B)  $2H/3$  from the ground.                      D)  $H/3$  from the ground.

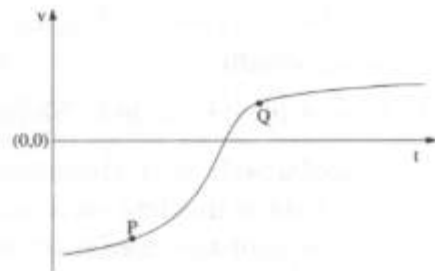
- 3.7 Two identical circular current carrying coils 1 and 2, each of radius  $R$  are placed adjacently a distance  $d$  apart ( $d \ll R$ ). They carry equal currents  $I$  in opposite sense. Let  $L_1$ ,  $L_2$ ,  $M_{12}$ , and  $M_{21}$  denote the self and mutual inductances.



Which of the following is at least approximately true?

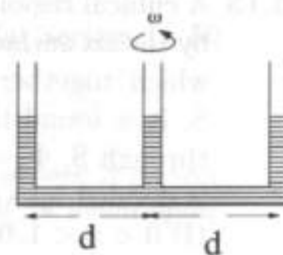
- A)  $|L_1| = |M_{21}|$ .                                      C)  $L_1 = -L_2$ .  
 B)  $M_{21} > L_1$ .                                      D)  $M_{12} = -M_{21}$ .
- 3.8 In a laboratory projectiles of mass  $m_1$  collide with a target of mass  $m_2$  at rest. It is observed that there are projectiles hurled at large scattering angles ( $> 150^\circ$ ). For this to happen
- A) the impact parameter of  $m_1$  must be small and  $m_1 < m_2$ .  
 B) the impact parameter of  $m_1$  must be large and  $m_1 > m_2$ .  
 C) the impact parameter of  $m_1$  must be small and  $m_1 > m_2$ .  
 D) the impact parameter of  $m_1$  must be large and  $m_1 < m_2$ .

- 3.9 Following is a graph of velocity ( $v$ ) versus time ( $t$ ) for a particle. Choose the correct statement among the following statements.



- A) Speed at P is more than at Q and displacement at P is less than at Q.  
 B) Acceleration at Q is less than that at P and displacement at Q is more than at P.  
 C) With time, acceleration at P is increasing while displacement is decreasing.  
 D) With time, acceleration at Q is increasing while displacement is also increasing.

- 3.10 A thin uniform tube in the shape of "W" containing a liquid is rotated about the central vertical column with constant angular speed  $\omega$ . If the separation between two adjacent columns is  $d$ , then



- A) The liquid in the central column rises a height  $(d\omega)^2/g$  above that of the outer columns.
- B) The liquid in the outer columns rises a height  $(d\omega)^2/g$  above that of the central column.
- C) The liquid in the outer columns rises a height  $(d\omega)^2/2g$  above that of the central column.
- D) The liquid in the central column rises a height  $2(d\omega)^2/g$  above that of the outer columns.

For questions 3.11 to 3.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

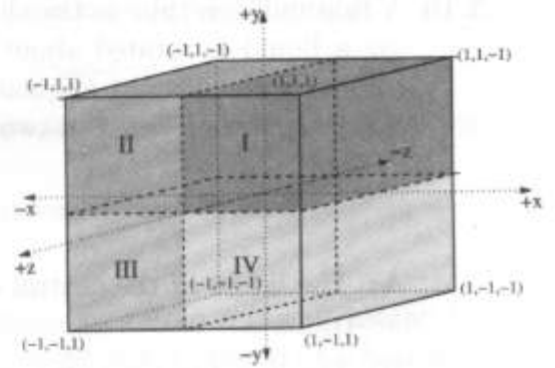
- 3.11 Two sinusoidal waves, whose displacements are given by  $y_1 = A \sin(2\pi\nu_1 t - k_1 x)$  and  $y_2 = A \sin(2\pi\nu_2 t - k_2 x)$ , are simultaneously present in a medium. Given that  $\nu_1 = 100$  Hz,  $\nu_2 = 200$  Hz,  $k_1 = \frac{2\pi}{3}$  m<sup>-1</sup> and  $k_2 = \frac{4\pi}{3}$  m<sup>-1</sup>, an observer located at the origin finds
- A) the maximum intensity at the origin is 2 times the maximum intensity due to each wave in the absence of the other.
- B) an intensity maximum at  $t = 0$  and an intensity minimum at  $t = \frac{1}{300}$  s at the origin.
- C) intensity minima at  $t = \frac{1}{300}$  s and at  $t = \frac{1}{200}$  s at the origin.
- D) the speed of the waves in the medium is 300 m s<sup>-1</sup>.
- 3.12 In an  $\alpha$ -decay of a nucleus of  $A = 200$  at rest in the laboratory, the  $Q$ -value is 5 MeV. Choose the correct statement(s).
- A) The de Broglie wavelengths of the emitted  $\alpha$  particle and of the recoil nucleus are equal.
- B) The de Broglie wavelength of the  $\alpha$  particle is approximately 1 Å.
- C) The kinetic energy of the  $\alpha$  particle and the recoil nucleus (as seen in the laboratory) are nearly equal.
- D) The kinetic energy of the  $\alpha$  particle is approximately 4.9 MeV.

**3.13** A cubical region (sides of 2 units) is bounded by the six surfaces:  $x = \pm 1, y = \pm 1, z = \pm 1$ , which together constitute a closed surface  $S$ . It is found that the net electrostatic flux through  $S, \Phi_S = 0$ . The volume of the cube is divided into 4 equal regions:

- (I)  $0 < x < 1, 0 < y < 1, -1 < z < 1$ ,
- (II)  $-1 < x < 0, 0 < y < 1, -1 < z < 1$ ,
- (III)  $-1 < x < 0, -1 < y < 0, -1 < z < 1$ ,
- and
- (IV)  $0 < x < 1, -1 < y < 0, -1 < z < 1$ .

It is found that  $|\Phi_I| \neq |\Phi_{II}|$ . We can conclude that

- A) there are no charges anywhere in  $S$ , since  $\Phi_S = 0$ .
- B) at least one of the regions I and II have charges present.
- C) at least one of  $\Phi_{III}$  and  $\Phi_{IV}$  is non-zero.
- D)  $|\Phi_I| + |\Phi_{II}| + |\Phi_{III}| + |\Phi_{IV}| > 0$ .



**3.14** A certain diatomic gas has the same specific heats as an ideal gas but a slightly different equation of state:  $PV = R(T + \alpha T^2)$ ,  $\alpha = 0.001 \text{ K}^{-1}$ . The temperature of the gas is raised from  $T_1 = 300 \text{ K}$  to  $T_2$  at constant pressure. It is found that work done on the gas is 70% higher than what would be on an ideal gas. Choose the correct statement(s).

- A)  $T_2 = 400 \text{ K}$ , internal energy increases by  $250R$  per mole.
- B)  $T_2 = 400 \text{ K}$ , internal energy increases by  $350R$  per mole.
- C) Total heat absorbed in the process is  $450R$  per mole.
- D) Total heat absorbed in the process is  $520R$  per mole.

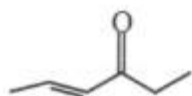
## Section 4 Chemistry

Total Marks for Section 4: 50

This section has 14 questions.

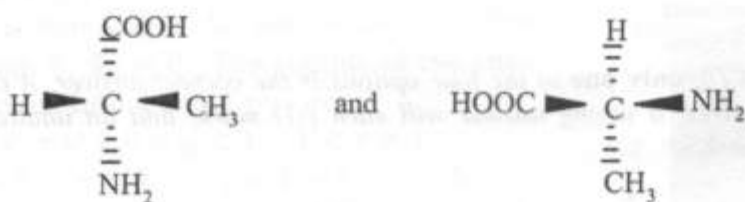
For questions 4.1 to 4.10, **only one** of the four options is the correct answer. A correct answer will earn 3 marks, a wrong answer will earn (-1) mark, and an unattempted question will earn 0 mark.

- 4.1. The metal ion whose hydrated form will be almost colourless is
- A)  $\text{Cu}^{2+}$                       C)  $\text{Na}^{2+}$   
B)  $\text{Mn}^{2+}$                       D)  $\text{Co}^{2+}$
- 4.2 For an ideal gas undergoing isothermal expansion (E: internal energy, S: entropy)
- A)  $\Delta E < 0, \Delta S > 0.$                       C)  $\Delta E = 0, \Delta S > 0$   
B)  $\Delta E = 0, \Delta S = 0.$                       D)  $\Delta E > 0, \Delta S > 0.$
- 4.3 The mixture of the solutions that will lead to formation of  $\text{CaF}_2$  precipitate is (solubility product of  $\text{CaF}_2 = 4 \times 10^{-11}$ )
- A) 100 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $2.0 \times 10^{-4} \text{ M F}^-$ .  
B) 50 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $2.0 \times 10^{-4} \text{ M F}^-$ .  
C) 100 mL of  $2.0 \times 10^{-4} \text{ M Ca}^{2+}$  is mixed with 50 mL of  $1.0 \times 10^{-4} \text{ M F}^-$ .  
D) 100 mL of  $2.0 \times 10^{-2} \text{ M Ca}^{2+}$  is mixed with 100 mL of  $6.0 \times 10^{-3} \text{ M F}^-$ .
- 4.4 The IUPAC name for the following compound is



- A) 3-hexenone.                      C) hex-3-on-4-ene.  
B) 2-hexene-4-one.                      D) 4-hexen-3-one.

4.5 The relationship between the following pair of compounds is



- A) enantiomers.                      C) homomers.  
B) diastereomers.                  D) geometrical isomers.

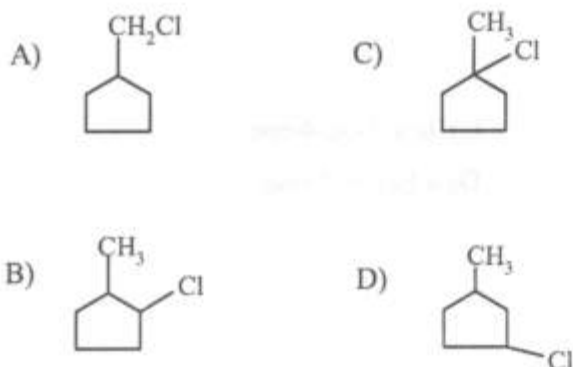
4.6 The molecule /ion with highest O-N-O bond angle is

- A)  $\text{NO}_2^-$                       C)  $\text{NO}_2^+$   
B)  $\text{NO}_3^-$                       D)  $\text{NO}_2$

4.7 Aluminum is extracted by electrolysis from Bauxite and this process is known as Hall-Heroult process. In this extraction, it is advantageous to use a mixture of bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) and  $\text{Na}_3\text{AlF}_6$ . The role of  $\text{Na}_3\text{AlF}_6$  in this mixture is

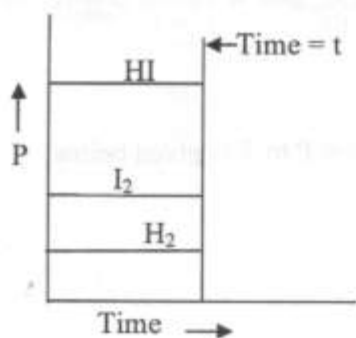
- A) to increase melting point of the mixture.  
B) to improve electrical conductivity of the cell.  
C) to convert bauxite into aluminium fluoride.  
D) to enrich the aluminum content of the ore.

4.8 Monochlorination of methylcyclopentane by chlorine, in the presence of light at low temperature, gives major product as

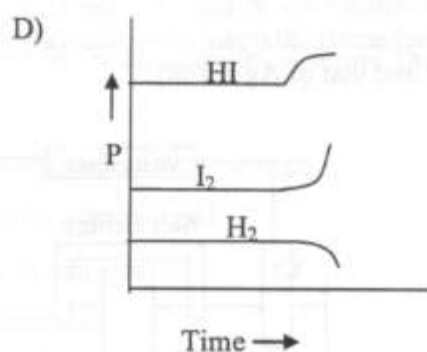
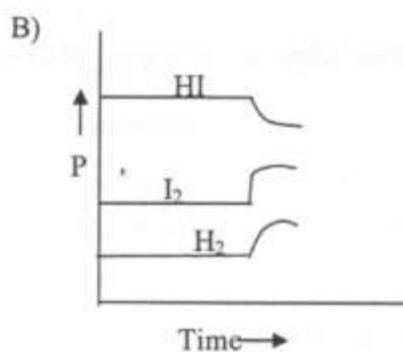
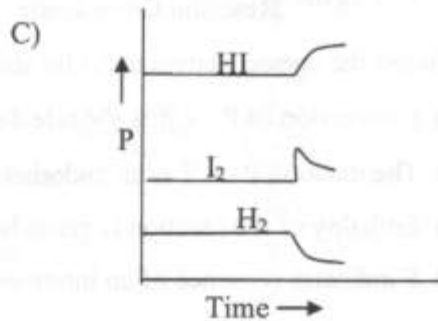
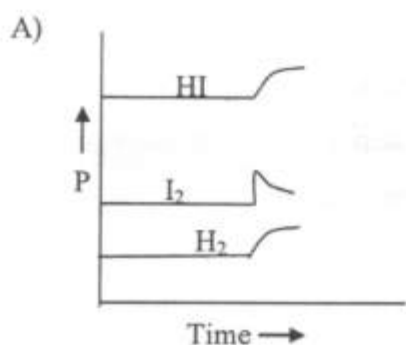




4.9 Consider gaseous reaction at equilibrium:  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ . The following figure qualitatively indicates pressure  $P$  for these gases at equilibrium in a container.



To this equilibrium system, at time  $t$ , an extra  $\text{I}_2(\text{g})$  is added. The set of curves that appropriately indicates the response of the system to the above situation is

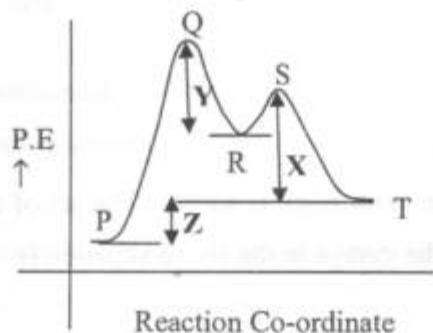


4.10 The solution that is most basic is

- A)  $[\text{H}_3\text{O}^+] = 10^{-9}$       C)  $\text{pH} = 8$   
 B)  $[\text{OH}^-] = 10^{-4}$       D)  $[\text{H}_3\text{O}^+] = 10^{-6}$

For questions 4.11 to 4.14, more than one of the four options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

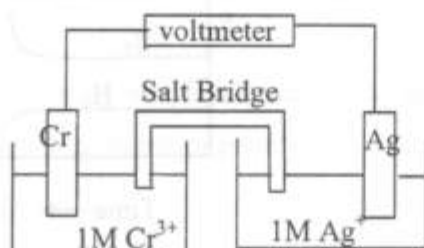
4.11 The potential energy curve for a reaction going from P to T is given below.



Choose the correct statement(s) for the above system.

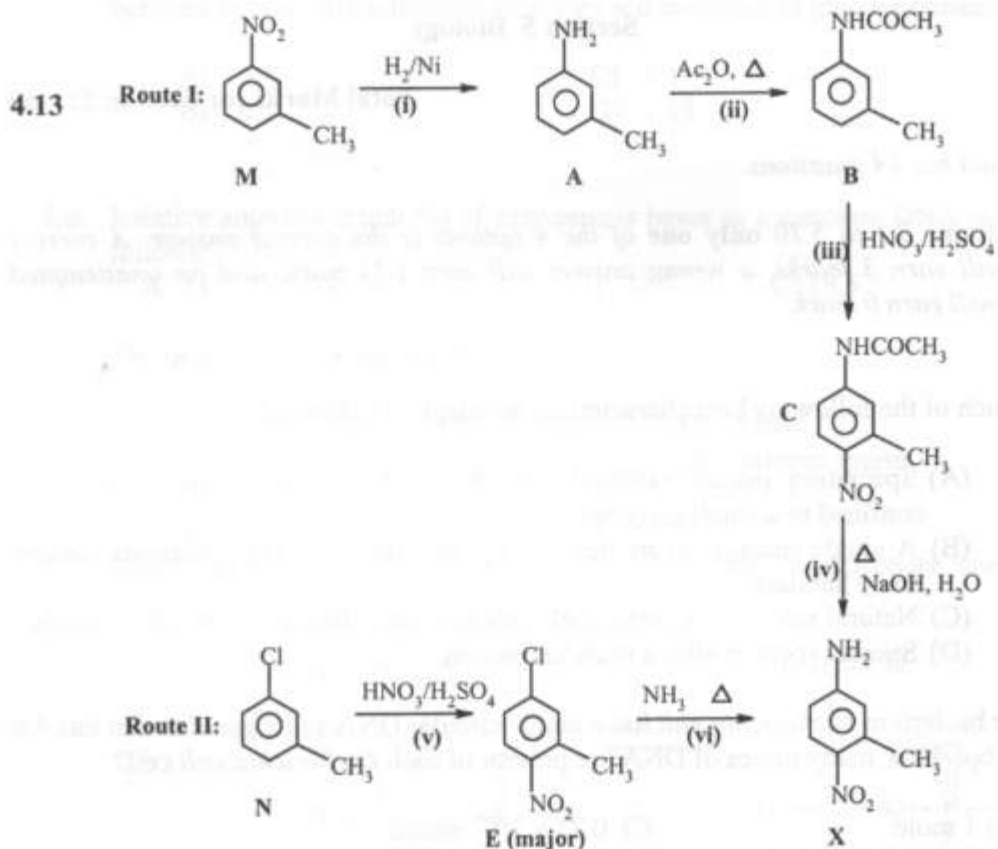
- A) Conversion of  $P \rightarrow R$  is the rate determining step of the overall reaction.
- B) The reaction  $P \rightarrow T$  is an endothermic reaction.
- C) Enthalpy of the reaction is given by  $Z + X$ .
- D) S indicates presence of an intermediate.

4.12 A schematic diagram of voltaic cell at  $25^\circ\text{C}$  is shown below (Atomic mass of Cr = 52 and that of Ag = 108).



Choose the correct statement(s) for the above system.

- A) The positive ions in the solution will migrate towards Ag half cell.
- B) The silver electrode will show increase in mass.
- C) If accidentally solid  $\text{Na}_2\text{S}$  falls into  $\text{Ag}^+$  electrode and turbidity is observed in silver half cell, the cell potential will decrease.
- D) When two moles of electrons are passed through the solution, the Cr electrode will lose its mass by about 35 g.



3-methyl-4-nitroaniline(X) can be prepared from M and N via routes I and II, respectively. Steps (i) to (vi) are involved in these routes. Choose the correct statement(s) for the above schemes.

- A) Steps (ii) and (iii) in route I are protection-deprotection steps.
- B) In route I, steps (ii) and (iii) can not be interchanged.
- C) In route II, step (vi) can be carried out easily on N.
- D) Nitration of M will give 2,5-dinitrotoluene.

4.14 Choose the correct statements for the series  $\text{BH}_3$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$ .

- A) The pKa values decrease from right to left.
- B) Lewis acidity increases from left to right.
- C) Bronsted acidity increases from left to right.
- D) The central atom in each molecule can have maximum of 8 electrons in its valence shell.

## Section 5 Biology

Total Marks for Section 5: 50

This section has 14 questions.

For Questions 5.1 to 5.10 **only one** of the 4 options is the correct answer. A correct answer will earn 3 marks, a wrong answer will earn (-1) mark, and an unattempted question will earn 0 mark.

5.1. Which of the following best characterizes an adaptive radiation?

- (A) Speciation occurs extremely rapidly, and descendent populations are confined to a small geographical area.
- (B) A single lineage diversifies rapidly, and descendent populations occupy many habitats.
- (C) Natural selection is particularly intense since disruptive selection occurs.
- (D) Species recover after a mass extinction.

5.2. The bacterium *Escherichia coli* has a single circular DNA as its genome that has  $4 \times 10^6$  bp. How many moles of DNA are present in each *Escherichia coli* cell?

- A) 1 mole.
- B)  $6.023 \times 10^{23}$  moles.
- C)  $0.25 \times 10^{-6}$  moles.
- D)  $1.66 \times 10^{-24}$  moles.

5.3. *Escherichia coli* cells were grown for many generations in  $^{15}\text{NH}_4\text{Cl}$  as sole nitrogen source. Subsequently, these cells were grown exactly for four generations in medium containing  $^{14}\text{NH}_4\text{Cl}$ . The DNA from these cells were isolated and separated. If  $^{15}\text{N}/^{15}\text{N}$  represents the two strands of DNA where both strands have heavy nitrogen;  $^{15}\text{N}/^{14}\text{N}$  as intermediate DNA; and  $^{14}\text{N}/^{14}\text{N}$  as DNA containing light nitrogen, the ratios for heavy: intermediate: light DNA, respectively would be

- A) 1:0:7
- B) 1:1:6
- C) 0:1:7
- D) 0:8:0

5.4. The Darwinian fitness can be estimated by

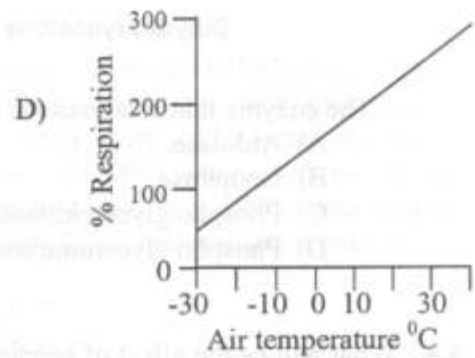
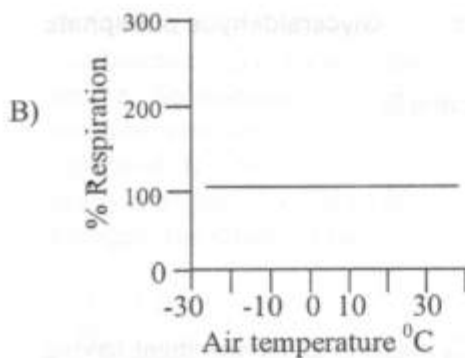
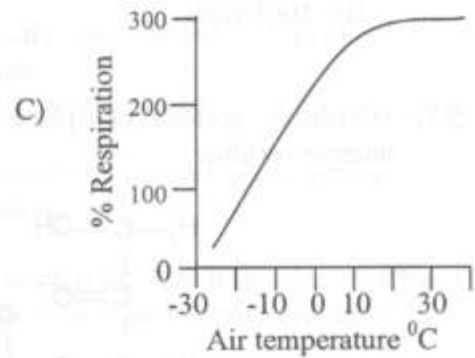
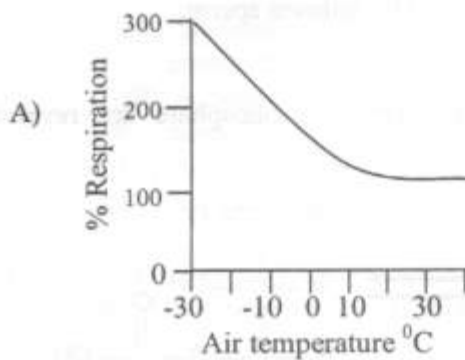
- (A) documenting how long different individuals in a population survive.
- (B) counting the number of offsprings produced by different individuals in a population.
- (C) determining which individuals have large size in a population.
- (D) determining which phenotype is the most common one in a given population.



5.9. Mitochondria are the sites of oxidative phosphorylation and electron transport. Hence, they are known as the powerhouse of the cell. Select the correct statement about these organelles.

- A) They are present in all prokaryotic and eukaryotic organisms.
- B) They are present only in aerobic prokaryotes and all eukaryotes.
- C) They are present in all living cells except viruses.
- D) They are present only in eukaryotes.

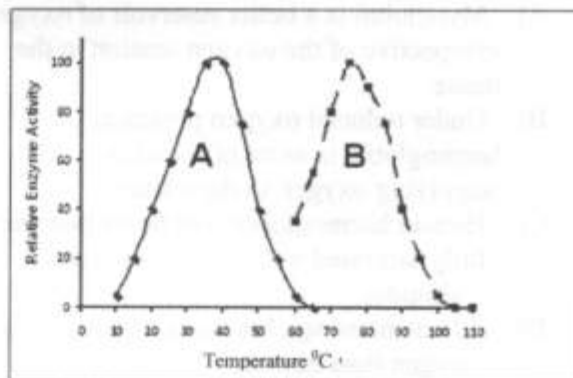
5.10. Which of the following graphs correctly depicts the rate of respiration of a non-hibernating mammal living in cold climate?



For Questions 5.11 to 5.14 more than one of the 4 options may be correct. Your answer is regarded correct only if you choose all the correct option(s) and no incorrect option(s). A correct answer will earn 5 marks, and a wrong answer or an unattempted question will earn 0 mark.

5.11. The following graph depicts the effect of temperature on the activity of the two enzymes A and B that catalyze the same reaction.

Choose the correct statement(s) for these results.



A) The rate of reaction in each case increases with increase in temperature and declines at higher temperatures due to denaturation of the enzyme.

B) Both the enzymes A and B are thermolabile.

C) At higher temperature, the reactants become highly energized and fail to interact with the active site, thus decreasing the rate of reaction.

D) The enzyme A is from a mesophilic organism, whereas the enzyme B is from a thermophilic organism.

5.12. Mutations in *Neurospora* were generated and screened to find out if some amino acids were required to support their growth. Following table depicts the results of screening of three such mutants (*Mut 1*, *2*, and *3*) that mapped to three genes (genes 1, 2 and 3, respectively):

Mutant Type	Gene	Supplement			
		no arginine no ornithine no citrulline	+ ARGININE no ornithine no citrulline	no arginine + ORNITHINE no citrulline	no arginine no ornithine + CITRULLINE
<i>Mut 1</i>	<i>Gene 1</i>	no growth	GROWTH	no growth	GROWTH
<i>Mut 2</i>	<i>Gene 2</i>	no growth	GROWTH	GROWTH	GROWTH
<i>Mut 3</i>	<i>Gene 3</i>	no growth	GROWTH	no growth	no growth

Choose the correct statement(s) for the above experiment.

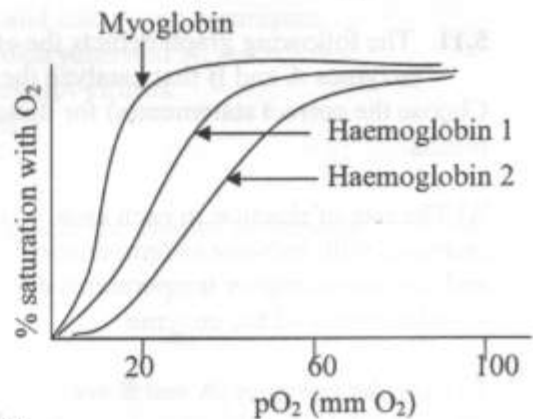
A) All the three genes code for enzymes in a pathway responsible for synthesis of arginine.

B) For the synthesis of arginine, ornithine and citrulline are the intermediates.

C) Gene 3 codes for an enzyme that catalyzes conversion of citrulline to arginine.

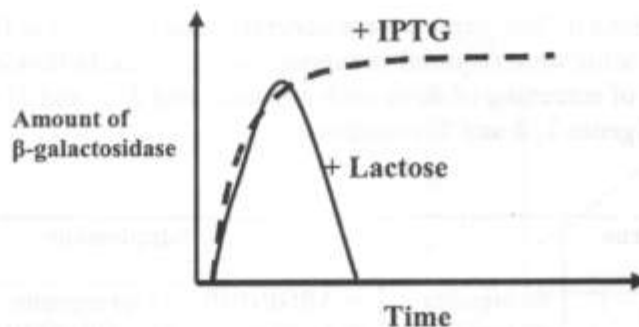
D) Gene 1 codes for an enzyme that catalyzes formation of ornithine from a precursor.

5.13. Haemoglobin and myoglobin are protein molecules that can bind to oxygen. Haemoglobin 1 in the graph is from Llama – a mammal living at high altitude and haemoglobin 2 belongs to human. Choose the correct interpretation(s) of the graph.



- A) Myoglobin is a better reservoir of oxygen irrespective of the oxygen tension in the tissue.
- B) Under reduced oxygen pressure, haemoglobin is more efficient in supplying oxygen to the tissues.
- C) Human haemoglobin will never become fully saturated with oxygen at high altitudes.
- D) Llama haemoglobin has a higher affinity for oxygen than human.

5.14. *Lac*-operon is an inducible operon that synthesizes  $\beta$ -galactosidase, an enzyme responsible for breakdown of lactose into galactose and glucose. Isopropyl thio galacto pyranoside (IPTG) is a structural analogue of lactose that also induces the *lac*-operon, but it cannot be broken down by  $\beta$ -galactosidase. The kinetics of activation of *lac*-operon by lactose and IPTG are shown below.



Choose the correct statement(s) for the above kinetics.

- A) The different kinetics could be because the IPTG has been added in very high concentration whereas lactose is added in limited quantity.
- B) Since lactose is also the substrate for  $\beta$ -galactosidase, the  $\beta$ -galactosidase that is induced degrades lactose. Consequently, the concentration of lactose decreases and hence the decline in the induction of *lac*-operon.
- C) Since IPTG is not a substrate for  $\beta$ -galactosidase, its concentration remains unaffected by the presence of enzyme. Consequently, the operon is continuously induced.
- D) Lactose binds to the repressor transiently, whereas IPTG binds permanently.

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