IIT JAM 2024 Biotechnology Question Paper with Solution

Time Allowed :3 Hours	Maximum Marks :100	Total Questions :60

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The examination duration is **3 Hours**. Manage your time effectively to attempt all questions within this period.

2. The total marks for this examination are **100**. Aim to maximize your score by strategically answering each question.

3. There are **60 mandatory questions** to be attempted in the paper. Ensure that all questions are answered.

4. Questions may appear in a **shuffled order**. Do not assume a fixed sequence and focus on each question as you proceed.

5. The **marking of answers** will be displayed as you answer. Use this feature to monitor your performance and adjust your strategy as needed.

6. You may **mark questions for review** and edit your answers later. Make sure to allocate time for reviewing marked questions before final submission.

7. Be aware of the detailed section and sub-section guidelines provided in the exam. **Understanding these will aid in effectively navigating the exam**.

Section A

Q.1 – Q.10 Carry ONE mark each

1. Which one of the following is a simple tissue system in plants?

(A) Epidermis

(B) Parenchyma

(C) Phloem

(D) Xylem

Correct Answer: (A). Epidermis

Explanation:

Simple tissues consist of one type of cell. Epidermis is a simple tissue that forms the outer protective covering of plants, helping prevent water loss and providing protection against mechanical injury. Complex tissues like xylem and phloem, however, are composed of more than one type of cell.

> Quick Tip
>
> Epidermis, being a simple tissue, is distinct from complex tissues such as xylem and phloem, which transport water and nutrients.

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2. In DNA replication, the Okazaki fragments are joined by:

(A) DNA helicase

(B) DNA ligase

(C) DNA polymerase

(D) DNA primase

Correct Answer: (B). DNA ligase

Explanation:

Okazaki fragments are short DNA segments synthesized on the lagging strand during replication. DNA ligase plays a critical role by sealing nicks between these fragments to

form a continuous DNA strand. Other enzymes like helicase and primase have distinct roles, such as unwinding DNA and synthesizing primers, respectively.

> **Quick Tip**
>
> Remember, DNA ligase acts like "molecular glue" to ensure DNA integrity.

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3. The most abundant type of RNA in a metabolically active mammalian cell is:

(A) mRNA

(B) rRNA

(C) snoRNA

(D) tRNA

Correct Answer: (B). rRNA

Explanation:

Ribosomal RNA (rRNA) constitutes about 80% of the total RNA in a cell. It is a key component of ribosomes, where protein synthesis occurs. In contrast, messenger RNA (mRNA) and transfer RNA (tRNA) make up smaller proportions and serve as intermediaries in protein synthesis.

> **Quick Tip**
>
> rRNA forms the structural and functional framework of ribosomes, which catalyze peptide bond formation.

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4. Which organelle in a eukaryotic cell is the site of the electron transport chain?

(A) Endoplasmic reticulum

(B) Golgi apparatus

(C) Mitochondrion

(D) Peroxisome

Correct Answer: (C). Mitochondrion

Explanation:

The electron transport chain is a series of protein complexes embedded in the inner mitochondrial membrane. These complexes transfer electrons and pump protons to create an electrochemical gradient, driving ATP synthesis. Other organelles, like the Golgi apparatus or peroxisomes, are not involved in this process.

> **Quick Tip**
>
> The mitochondrion is often called the "powerhouse of the cell" because of its role in ATP production.

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5. RNA is a polymer of:

(A) Glycosides

(B) Ribonucleosides

(C) Ribonucleotides

(D) Riboses

Correct Answer: (C). Ribonucleotides

Explanation:

RNA is composed of ribonucleotides, each containing a ribose sugar, a phosphate group, and a nitrogenous base (adenine, uracil, cytosine, or guanine). This structure forms the backbone of RNA, enabling its various functions in cells, including protein synthesis.

> **Quick Tip**
>
> RNA differs from DNA by having uracil instead of thymine and ribose sugar instead of deoxyribose.

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6. Which one of the following is present in a bacterial cell?

(A) 28S rRNA

(B) 70S ribosome

(C) Chitinous cell wall

(D) Histones

Correct Answer: (B). 70S ribosome

Explanation:

Bacteria possess 70S ribosomes, which are smaller than the 80S ribosomes found in eukaryotes. They lack chitinous cell walls, which are characteristic of fungi, and histones, which are associated with eukaryotic chromatin.

> **Quick Tip**
>
> 70S ribosomes in bacteria are composed of a 50S large subunit and a 30S small subunit.

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7. Which color of light excites a natural GFP to emit green fluorescence?

(A) Blue

(B) Green

(C) Infrared

(D) Red

Correct Answer: (A). Blue

Explanation:

Green fluorescent protein (GFP) absorbs blue light and emits green fluorescence due to its specific chromophore structure.

> **Quick Tip**
>
> GFP is widely used in molecular biology as a reporter gene to visualize protein localization and expression.

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8. Which one of the following hormones promotes fruit ripening?

(A) Abscisic acid

(B) Auxin

(C) Ethylene

(D) Gibberellin

Correct Answer: (C). Ethylene

Explanation:

Ethylene is a plant hormone that promotes fruit ripening by triggering enzymes involved in cell wall degradation, starch-to-sugar conversion, and pigment synthesis.

> **Quick Tip**
>
> Ethylene is commercially used in agriculture to ripen fruits like bananas and tomatoes.

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9. Which one of the following has a catalytic RNA?

(A) Ribonuclease H

(B) Ribozyme

(C) RNA polymerase I

(D) RNA polymerase II

Correct Answer: (B). Ribozyme

Explanation:

Ribozymes are RNA molecules with catalytic activity, capable of cleaving RNA and participating in RNA splicing. They are distinct from proteins with enzymatic activity.

> **Quick Tip**
>
> An example of a ribozyme is the self-splicing intron in Tetrahymena thermophila.

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10. The number of significant figures in a reported measurement of 0.00361 is:

(A) 3

(B) 4

(C) 5

(D) 6

Correct Answer: (B). 4

Explanation:

Significant figures are all the digits that are known accurately, plus one uncertain digit. In 0.00361, the first three zeros are placeholders and do not count as significant figures.

> **Quick Tip**
>
> To determine significant figures, focus on non-zero digits and zeros between them or after a decimal point.

Section A

Q.11 – Q.30 Carry TWO marks each

11. Match the terminology in Group I with the stimulus in Group II that generates growth response of plants.

Group I: P. Gravitropism Q. Phototropism R. Thigmotropism S. Chemotropism

Group II: 1. Light 2. Touch 3. Chemical 4. Gravity

(A) P – 3, Q – 4, R – 2, S – 1

(B) P – 2, Q – 1, R – 3, S – 4

(C) P – 4, Q – 1, R – 2, S – 3

(D) P – 4, Q – 2, R – 1, S – 3

Correct Answer: (C). P – 4, Q – 1, R – 2, S – 3

Explanation:

Gravitropism refers to growth towards or away from gravity. Phototropism involves a response to light.

Thigmotropism is a response to touch, seen in climbing plants. Chemotropism is the response to chemical stimuli, such as pollen tube growth.

> **Quick Tip**
>
> Gravitropism is commonly observed in roots (positive) and shoots (negative). Remember, the suffix "-tropism" refers to a directional growth response.

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12. The correct hierarchy of taxa in the Linnaean classification of eukaryotes is:

(A) Kingdom, class, phylum, order, family, genus

(B) Kingdom, order, class, phylum, family, genus

(C) Kingdom, phylum, order, family, class, genus

(D) Kingdom, phylum, class, order, family, genus

Correct Answer: (D). Kingdom, phylum, class, order, family, genus

Explanation:

The Linnaean system classifies living organisms into hierarchical ranks: Kingdom > Phylum > Class > Order > Family > Genus > Species. This taxonomy reflects increasing specificity from Kingdom to Genus.

> **Quick Tip**
>
> To remember the order, use the mnemonic: **King Philip Came Over For Good Soup.**

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13. Which one of the following statements about polyploidy is correct?

(A) Autopolyploids are derived from a single species.

(B) Autopolyploids are derived from two different species.

(C) Allopolyploids are derived from a single species.

(D) Allopolyploids are not fertile when mated with each other.

Correct Answer: (A). Autopolyploids are derived from a single species.

Explanation:

Polyploidy involves an organism having multiple sets of chromosomes. - Autopolyploids originate from chromosome duplication within a single species. - Allopolyploids arise from hybridization between two species.

> **Quick Tip**
>
> Examples of polyploidy include wheat (allopolyploid) and bananas (autopolyploid).

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14. Which one of the following hormones is a tyrosine derivative?

(A) Epinephrine

(B) Estradiol

(C) Progesterone

(D) Testosterone

Correct Answer: (A). Epinephrine

Explanation:

Epinephrine, also known as adrenaline, is synthesized from the amino acid tyrosine. Other options like estradiol, progesterone, and testosterone are steroid hormones derived from cholesterol.

> **Quick Tip**
>
> Epinephrine plays a crucial role in the "fight or flight" response by increasing heart rate and energy supply.

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15. Which one of the following immunoglobulins crosses the human placenta?

(A) IgA

(B) IgE

(C) IgG

(D) IgM

Correct Answer: (C). IgG

Explanation:

IgG is the only immunoglobulin that can cross the placenta, providing passive immunity to the fetus. Other antibodies like IgA and IgM do not cross the placenta.

> **Quick Tip**
>
> IgG is vital for newborn immunity as it protects against bacterial and viral infections.

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16. Determine the correctness or otherwise of the following Assertion (A) and the Reason (R).

Assertion (A): The resolving power of a transmission electron microscope is higher than that of the light microscope.

Reason (R): The wavelength of electrons is shorter than that of visible light.

(A) Both (A) and (R) are true and (R) is the correct reason for (A).

(B) Both (A) and (R) are true but (R) is not the correct reason for (A).

(C) Both (A) and (R) are false.

(D) (A) is true but (R) is false.

Correct Answer: (A). Both (A) and (R) are true and (R) is the correct reason for (A).

Explanation:

The resolving power of a microscope depends on the wavelength of the source used. Electron microscopes use electrons with wavelengths much shorter than visible light, allowing them to achieve higher resolution.

> **Quick Tip**
>
> Remember: Shorter wavelengths provide higher resolution in microscopy.

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17. Match the morphology in Group I with the corresponding microorganism in Group II.

Group I: P. Coccus Q. Rod R. Comma S. Spiral

Group II: 1. Treponema 2. Bacillus 3. Neisseria 4. Vibrio

(A) P – 3, Q – 2, R – 4, S – 1

(B) P – 4, Q – 1, R – 3, S – 2

(C) P – 2, Q – 4, R – 1, S – 3

(D) P – 1, Q – 2, R – 3, S – 4

Correct Answer: (A). P – 3, Q – 2, R – 4, S – 1

Explanation:

Coccus refers to spherical bacteria, e.g., Neisseria. Rod morphology is seen in Bacillus. Comma-shaped bacteria are represented by Vibrio. Spiral morphology is characteristic of Treponema.

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18. Which one of the following genetic crosses and their results indicates cytoplasmic inheritance?

(A) Wild-type male × mutant female → 100% progeny are mutant

(B) Wild-type male × mutant female → 25% progeny are wild-type

(C) Mutant male × wild-type female → 50% progeny are mutant

(D) Mutant male × wild-type female → 75% progeny are wild-type

Correct Answer: (A). Wild-type male × mutant female → 100% progeny are mutant

Explanation:

Cytoplasmic inheritance involves genes in organelles like mitochondria, which are inherited maternally. All offspring inherit the mother's cytoplasmic traits.

> **Quick Tip**
>
> Traits encoded in mitochondria or chloroplasts follow maternal inheritance patterns.

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19. Which of the following is NOT a characteristic morphological feature of apoptotic cells?

(A) Disassembly of nuclear envelope

(B) DNA fragmentation

(C) Increased cell size

(D) Membrane blebbing

Correct Answer: (C). Increased cell size

Explanation:

During apoptosis, cells undergo shrinkage, not enlargement. Other features like DNA fragmentation and membrane blebbing are typical of apoptosis.

20. Competition between two populations in an ecosystem is:

(A) Beneficial (+) to both the populations

(B) Deleterious (-) to both the populations

(C) Beneficial (+) to one population, but deleterious (-) to the other population

(D) Beneficial (+) to one population, but no effect (0) on the other population

Correct Answer: (B). Deleterious (-) to both the populations

Explanation:

Competition occurs when two populations vie for the same limited resource, negatively impacting both populations as resources become scarce.

21. Adenine constitutes 0.16 mole fraction in a given single-stranded DNA. What is the mole fraction of uracil in the resultant RNA, if this entire DNA fragment is transcribed?

(A) 0.16

(B) 0.32

(C) 0.34

(D) 0.68

Correct Answer: (A). 0.16

Explanation:

In transcription, adenine in the DNA template pairs with uracil in RNA. Since adenine's mole fraction in DNA is 0.16, uracil's mole fraction in RNA will also be 0.16.

22. Which one of the following is NOT used as a component in subunit vaccines?

(A) Capsular polysaccharide

(B) Inactivated exotoxin

(C) Inactivated virus

(D) Viral glycoprotein

Correct Answer: (C). Inactivated virus

Explanation:

Subunit vaccines include only specific parts of the pathogen, such as capsular polysaccharides, inactivated exotoxins, or viral glycoproteins, and not the entire inactivated virus.

23. Metabolic acidosis is associated with decreased plasma level of:

(A) Bicarbonate

(B) Lactate

(C) Oxygen

(D) Urea

Correct Answer: (A). Bicarbonate

Explanation:

Metabolic acidosis is caused by the accumulation of acids or loss of bicarbonate, leading to reduced plasma bicarbonate levels and a drop in blood pH.

24. Genes in two species that are derived from the same ancestral gene in their most recent common ancestor are called:

(A) Analogs

(B) Heterologs

(C) Orthologs

(D) Paralogs

Correct Answer: (C). Orthologs

Explanation:

Orthologs are genes in different species that evolved from a common ancestral gene. They retain the same function across species, unlike paralogs, which arise by duplication within the same genome.

25. An object is placed 15 cm in front of a convex mirror, which has a radius of curvature 30 cm. Which one of the following is true of the image formed?

(A) Real and inverted

(B) Real and upright

(C) Virtual and inverted

(D) Virtual and upright

Correct Answer: (D). Virtual and upright

Explanation:

Convex mirrors always produce virtual, upright, and diminished images regardless of the object's position. Using the mirror equation confirms this result.

26. If a variable z shows a standard normal distribution, then the percent probability that $0 \leq z^2 \leq 1$ is:

(A) 34

(B) 68

(C) 95

(D) 99

Correct Answer: (B). 68

Explanation:

The standard normal distribution has 68% of its probability within one standard deviation of the mean. Since z^2 is bounded between 0 and 1, the percentage probability is 68%.

Quick Tip

For a quick recall: $68\% - 95\% - 99.7\%$ rule applies for standard normal distributions (1, 2, and 3 standard deviations).

27. In the chick embryo, the ectoderm generates:

(A) Alveolar cells

(B) Germ cells

(C) Neurons

(D) Red blood cells

Correct Answer: (C). Neurons

Explanation:

The ectoderm layer gives rise to the nervous system, including neurons, and also forms the epidermis of the skin.

**28. The boiling points of Iodomethane, Dibromomethane, Bromomethane,
Chloromethane follow the order:**

(A) Bromomethane > Dibromomethane > Iodomethane > Chloromethane

(B) Bromomethane > Iodomethane > Chloromethane > Dibromomethane

(C) Dibromomethane > Iodomethane > Bromomethane > Chloromethane

(D) Iodomethane > Bromomethane > Chloromethane > Dibromomethane

Correct Answer: (C).Dibromomethane > Iodomethane > Bromomethane > Chloromethane

Explanation:

Boiling points depend on molecular weight and intermolecular forces. Dibromomethane has
the highest boiling point due to its greater molecular weight and polarity compared to the
others.

29. Chromosome duplication during the cell cycle occurs in:

(A) G1 phase

(B) G2 phase

(C) M phase

(D) S phase

Correct Answer: (D). S phase

Explanation:

DNA replication occurs in the S (synthesis) phase of the cell cycle, ensuring that each
daughter cell receives an identical set of chromosomes.

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30. Ionic character of the covalent bonds in the compounds $Cl_2, HCl, NaCl, NaF$ **follows the order:**

(A) $Cl_2 > NaCl > HCl > NaF$

(B) $HCl > Cl_2 > NaF > NaCl$

(C) $HCl > NaCl > NaF > Cl_2$

(D) $NaF > NaCl > HCl > Cl_2$

Correct Answer: (D). $NaF > NaCl > HCl > Cl_2$

Explanation:

Ionic character depends on the electronegativity difference between bonded atoms. NaF has the highest ionic character due to the large difference between sodium and fluorine.

Section B

Q.31 – Q.40 Carry TWO marks each.

31. Which of the following is/are lateral meristems?

(A) Cork cambium

(B) Procambium

(C) Protoderm

(D) Vascular cambium

Correct Answer: (A) and (D)

Explanation:

Lateral meristems, such as cork cambium and vascular cambium, are responsible for secondary growth in plants, increasing the girth. Procambium and protoderm are primary

meristems involved in elongation.

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32. Which of the following statement(s) about Golden Rice is/are correct?

(A) Consumption of it increases vitamin A levels

(B) Consumption of it increases vitamin D levels

(C) Consumption of it increases vitamin K levels

(D) It is a transgenic crop containing β-carotene

Correct Answer: (A) and (D)

Explanation:

Golden Rice is genetically engineered to contain β-carotene, a precursor to vitamin A, addressing vitamin A deficiency. It does not affect vitamin D or K levels.

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33. Which of the following statement(s) about eukaryotic DNA topoisomerase is/are correct?

(A) Topoisomerase I creates transient single-strand breaks

(B) Topoisomerase I creates transient double-strand breaks

(C) Topoisomerase II creates transient single-strand breaks

(D) Topoisomerase II creates transient double-strand breaks

Correct Answer: (A) and (D)

Explanation:

Topoisomerase I relaxes supercoils by creating single-strand breaks, while Topoisomerase II creates double-strand breaks to untangle DNA during replication.

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34. Which of the following method(s) is/are used to estimate protein concentration?

(A) Anthrone

(B) Biuret

(C) Bradford

(D) Lowry

Correct Answer: (B), (C), and (D)

Explanation:

The Biuret, Bradford, and Lowry methods involve colorimetric techniques for estimating protein concentrations. Anthrone is used for carbohydrate estimation.

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35. Which of the following is/are example(s) of a lotic ecosystem?

(A) Lake

(B) Pond

(C) River

(D) Stream

Correct Answer: (C) and (D)

Explanation:

Lotic ecosystems involve flowing water, such as rivers and streams. Lakes and ponds are lentic (standing water) ecosystems.

36. Which of the following statement(s) about the effect of genetic drift is/are correct?

(A) It can cause changes in the frequency of alleles at random

(B) It is a mechanism of evolution

(C) It can lead to loss of genetic variation within small populations

(D) It is significant in large populations

Correct Answer: (A), (B), and (C)

Explanation:

Genetic drift is a random process that can cause unpredictable changes in allele frequencies, particularly in small populations. It is one of the mechanisms of evolution and can lead to a loss of genetic variation over time. However, its effects are not significant in large populations due to the stabilizing impact of larger gene pools.

> Quick Tip
>
> Genetic drift is most impactful in small populations and contributes to evolutionary changes by random sampling effects.

37. Which of the following technique(s) can be used to determine the three-dimensional structure of an organic compound?

(A) Mass spectrometry

(B) NMR spectroscopy

(C) UV-visible spectroscopy

(D) X-ray crystallography

Correct Answer: (B) and (D)

Explanation:

NMR spectroscopy and X-ray crystallography are widely used for determining the three-dimensional structure of organic compounds. NMR spectroscopy provides information about molecular structure through interactions of nuclear spins, while X-ray crystallography directly visualizes the molecular arrangement using crystal diffraction data.

38. Which of the following entity(ies) is/are found inside the intact nucleus of eukaryotic cells?

(A) Centrosome

(B) Lysosome

(C) Nucleolus

(D) Nucleosome

Correct Answer: (C) and (D)

Explanation:

Within the nucleus of eukaryotic cells, the nucleolus is responsible for ribosomal RNA synthesis and assembly, while nucleosomes are the fundamental units of chromatin, consisting of DNA wrapped around histone proteins. Centrosomes and lysosomes are located outside the nucleus.

39. Which of the following is/are trace element(s)?

(A) Mn

(B) P

(C) S

(D) Zn

Correct Answer: (A) and (D)

Explanation:

Trace elements such as manganese (Mn) and zinc (Zn) are required in small quantities for enzymatic and metabolic activities. Phosphorus (P) and sulfur (S) are macronutrients needed in larger amounts for cellular functions.

> **Quick Tip**
>
> Trace elements play vital roles as cofactors in enzymatic reactions but are required only in minute amounts.

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40. Which of the following is/are true about Retrovirus?

(A) It contains double-stranded RNA genome

(B) It can cause cancer

(C) It contains reverse transcriptase

(D) It contains double-stranded DNA genome

Correct Answer: (B) and (C)

Explanation:

Retroviruses, such as HIV, possess reverse transcriptase, which converts RNA into DNA during infection. They can integrate into the host genome, sometimes leading to oncogenesis. They do not have a double-stranded RNA or DNA genome; their genome is single-stranded RNA.

> **Quick Tip**
>
> Reverse transcriptase is a hallmark of retroviruses, enabling them to replicate within host DNA.

Section C

Q.41 – Q.50 Carry ONE mark each

41. A wooden plant accumulates 10 mg/kg of ^{14}C during its life span. A fossil of this plant was discovered and contains 2.5 mg/kg of ^{14}C. The age of this fossil at the time of discovery is (use 5730 years as the half-life of ^{14}C):

Correct Answer: 11460 to 11460 years

Explanation:

Using the half-life formula:

$$t = \frac{\ln(N_0/N)}{\ln(2)} \times T_{1/2}$$

where $N_0 = 10$, $N = 2.5$, and $T_{1/2} = 5730$ years. Substituting the values:

$$t = \frac{\ln(10/2.5)}{\ln(2)} \times 5730 = 11460 \,\text{years}.$$

> **Quick Tip**
>
> ^{14}C dating is widely used for estimating the age of organic materials based on the decay of carbon isotopes.

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42. A cylinder contains 50 L of an ideal gas at a pressure of 50 atm. Assuming that the temperature remains unchanged, the volume of the gas at 1 atm is:

Correct Answer: 2500 L

Explanation:

Using Boyle's law:

$$P_1V_1 = P_2V_2,$$

substitute $P_1 = 50 \,\text{atm}$, $V_1 = 50 \,\text{L}$, and $P_2 = 1 \,\text{atm}$:

$$V_2 = \frac{P_1V_1}{P_2} = \frac{50 \times 50}{1} = 2500 \,\text{L}.$$

> **Quick Tip**
>
> Boyle's law states that for a constant temperature, pressure and volume are inversely proportional.

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43. One molecule of the protein myoglobin contains one atom of iron. A myoglobin sample was found to contain 0.34% iron. The molecular weight of myoglobin is (use atomic mass of iron = 55.9 g/mol):

Correct Answer: 16440 to 16445 g/mol

Explanation:

The molecular weight of myoglobin can be calculated as:

$$\text{Molecular weight} = \frac{\text{Mass of Fe} \times 100}{\% \text{of Fe}} = \frac{55.9 \times 100}{0.34} = 16441.18 \,\text{g/mol.}$$

> **Quick Tip**
>
> The percentage composition formula is useful for estimating molecular weights of compounds.

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44. The wavelength of visible light for the green color is 600 nm. The energy of photons of this color is (Planck's constant $h = 6.63 \times 10^{-34}$ J·s, $1\,eV = 1.6 \times 10^{-19}$ J, speed of light $c = 3 \times 10^8$ m/s):

Correct Answer: 2.0 to 2.2 eV

Explanation:

Using the energy formula:

$$E = \frac{h \cdot c}{\lambda},$$

substitute $h = 6.63 \times 10^{-34}$, $c = 3 \times 10^8$, and $\lambda = 600\,\text{nm} = 600 \times 10^{-9}$ m:

$$E = \frac{6.63 \times 10^{-34} \cdot 3 \times 10^8}{600 \times 10^{-9}} = 3.315 \times 10^{-19}\,\text{J.}$$

Convert to electronvolts:

$$E = \frac{3.315 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.07\,\text{eV.}$$

> **Quick Tip**
>
> Photon energy is inversely proportional to its wavelength, with shorter wavelengths having higher energy.

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45. A ball dropped from a bridge hits the surface of the water in 3 s. The height of the bridge, ignoring air resistance, is (use $g = 9.8$ m/s^2):

Correct Answer: 44.1 to 44.1 m

Explanation:

Using the equation of motion:

$$s = \frac{1}{2}gt^2,$$

substitute $g = 9.8\,\text{m/s}^2$ and $t = 3\,\text{s}$:

$$s = \frac{1}{2} \times 9.8 \times (3)^2 = 44.1\,\text{m}.$$

> Quick Tip
>
> Objects in free fall under gravity follow a quadratic relation with time, with displacement proportional to t^2.

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46. For a given square, if the area of its incircle is 100 cm^2, then the area of its circumcircle is:

Correct Answer: $200\,\text{cm}^2$

Explanation:

The radius of the incircle is given by:

$$r = \sqrt{\frac{\text{Area of incircle}}{\pi}} = \sqrt{\frac{100}{\pi}}.$$

The radius of the circumcircle is $\sqrt{2}$ times the radius of the incircle:

$$R = \sqrt{2} \cdot r = \sqrt{2} \cdot \sqrt{\frac{100}{\pi}}.$$

The area of the circumcircle is:

$$\text{Area} = \pi R^2 = \pi \left(\sqrt{2} \cdot \sqrt{\frac{100}{\pi}} \right)^2 = 200\,\text{cm}^2.$$

> Quick Tip
>
> The circumcircle's radius is always $\sqrt{2}$ times the incircle's radius for a square.

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47. The number of peaks in the ^{1}H NMR spectrum of methoxymethane (CH$_3$OCH$_3$) is:

Correct Answer: 1

Explanation:

Methoxymethane (dimethyl ether) has two equivalent methyl groups (CH_3) attached to the same oxygen atom. Since all hydrogen atoms in the molecule are chemically equivalent, the ^{1}H NMR spectrum shows only one peak.

> **Quick Tip**
>
> Symmetry in a molecule leads to fewer distinct peaks in an NMR spectrum.

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48. The amount of agarose required to prepare 250 mL of 0.8% agarose gel is:

Correct Answer: 2 g

Explanation:

The weight of agarose required is calculated as:

$$\text{Weight} = \text{Concentration} \times \text{Volume}.$$

Substitute 0.8% (0.8 g/100 mL) and 250 mL:

$$\text{Weight} = 0.8 \times \frac{250}{100} = 2\,\text{g}.$$

> **Quick Tip**
>
> Percentage solutions are calculated based on weight per 100 mL of solution.

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49. Three genes x, y, and z are located on a chromosome in a linear order. If the recombination frequencies between x and y is 0.15, and between y and z is 0.10, the expected frequency of double crossovers is:

Correct Answer: 0.015

Explanation:

The frequency of double crossovers is the product of individual recombination frequencies:

$$\text{Double crossover frequency} = 0.15 \times 0.10 = 0.015.$$

50. A bacterial cell suspension contains 2×10^5 cells/mL. The volume of this suspension required to obtain 1.4×10^6 cells is:

Correct Answer: 7 mL

Explanation:

The required volume is calculated using the formula:

$$\text{Volume} = \frac{\text{Total cells required}}{\text{Cell concentration per mL}}.$$

Substitute 1.4×10^6 cells and 2×10^5 cells/mL:

$$\text{Volume} = \frac{1.4 \times 10^6}{2 \times 10^5} = 7\,\text{mL}.$$

Section C

Q.51 – Q.60 Carry TWO marks each.

51. The data provided in the table were obtained from the following reaction, carried out at 273 K:

$$A + B \rightarrow C$$

Initial concentration of [A]	Initial concentration of [B]	Initial rate of formation of [C]
0.2 mol/L	0.2 mol/L	0.3 mol/L/s
0.4 mol/L	0.2 mol/L	0.6 mol/L/s
0.4 mol/L	0.4 mol/L	2.4 mol/L/s

The order of the reaction with respect to [A] is:
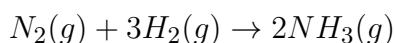
Correct Answer: 1

Explanation:

To determine the order with respect to A, we compare the initial rates for the same concentration of [B]. The rate doubles as [A] doubles, indicating the order is 1 with respect to A.

> **Quick Tip**
>
> When the rate doubles as the concentration of a reactant doubles, the order is 1 with respect to that reactant.

---

52. Ammonia is synthesized in the Haber process in the following reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The temperature above which the reaction becomes spontaneous is:

Correct Answer: 463.0 K

Explanation:

The temperature for spontaneity can be found using the Gibbs free energy equation:

$$\Delta G = \Delta H - T\Delta S$$

For spontaneity, $\Delta G = 0$. Substituting the given values $\Delta H = -92.2 \, \text{kJ/mol}$ and $\Delta S = -199 \, \text{J/K}$:

$$0 = -92.2 \times 10^3 - T \times (-199)$$

Solving for T:

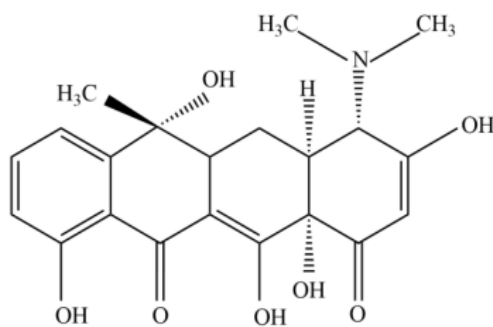$$T = \frac{92.2 \times 10^3}{199} = 463.0 \, \text{K}.$$

> **Quick Tip**
>
> The temperature at which a reaction becomes spontaneous is calculated when $\Delta G = 0$.

---

53. In the given molecule, the number of chiral centers is:

Correct Answer: 5

Explanation:

A chiral center is a carbon atom bonded to four different groups. The molecule shown contains 5 such centers.

> **Quick Tip**
>
> Look for carbon atoms bonded to four different groups to identify chiral centers.

---

54. Two resistors of 2 Ω and 4 Ω are combined in parallel. If this combination is connected to a battery of 16 V, the maximum current that can be drawn from the battery is:

Correct Answer: 12 A

Explanation:

The total resistance R_{total} of the parallel combination is:

$$\frac{1}{R_{\text{total}}} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4},$$

so $R_{\text{total}} = \frac{4}{3}\,\Omega$. Using Ohm's law:

$$I = \frac{V}{R_{\text{total}}} = \frac{16}{\frac{4}{3}} = 12\,\text{A}.$$

> **Quick Tip**
>
> In parallel combinations, the total resistance is always lower than the smallest individual resistance.

55. A box of mass 20 kg is pulled at constant speed across a floor by a rope. The rope makes an angle of 45° with the horizontal. Assuming that friction is negligible, the work done in pulling the box by a distance of 20 m is:

Correct Answer: 2740 J

Explanation:

The work done W is given by:

$$W = F \cdot d \cdot \cos(\theta),$$

where F is the force, d is the distance, and θ is the angle. The force applied is $F = mg$, so:

$$W = 20 \times 9.8 \times 20 \times \cos(45°) = 2740\,\text{J}.$$

> **Quick Tip**
>
> The work done by a force at an angle is calculated by multiplying the force, displacement, and the cosine of the angle between them.

---

56. Consider an enzyme that follows simple Michaelis-Menten kinetics, and has a K_M of 5 µM. The initial velocity of the reaction will be 10 percent of the maximum velocity at a substrate concentration of:

Correct Answer: 0.54 µM

Explanation:

For Michaelis-Menten kinetics, the initial velocity (v_0) at 10

$$v_0 = 0.1 \cdot V_{\text{max}}.$$

The formula for the reaction velocity is:

$$v_0 = \frac{V_{\text{max}}[S]}{K_M + [S]}.$$

Setting $v_0 = 0.1 V_{\text{max}}$ and solving for $[S]$:

$$0.1 = \frac{[S]}{K_M + [S]}.$$

Substitute $K_M = 5$:

$$0.1 = \frac{[S]}{5 + [S]},$$

$$0.1(5 + [S]) = [S],$$

$$0.5 + 0.1[S] = [S],$$

$$0.5 = 0.9[S],$$

$$[S] = \frac{0.5}{0.9} = 0.54\,\mu M.$$

> **Quick Tip**
>
> For 10 percent of the maximum velocity, the substrate concentration is approximately $\frac{K_M}{9}$.

---

57. The value of:

$$\lim_{x \to 3} \frac{x^2 - 9}{x^2 - 4x + 3}$$

Correct Answer: 3

Explanation:

Factorize both the numerator and denominator:

$$x^2 - 9 = (x - 3)(x + 3),$$

$$x^2 - 4x + 3 = (x - 3)(x - 1).$$

So, the expression becomes:
$$\frac{(x - 3)(x + 3)}{(x - 3)(x - 1)}.$$

Cancel out the $(x - 3)$ terms:
$$\frac{x + 3}{x - 1}.$$

Substitute $x = 3$:
$$\frac{3 + 3}{3 - 1} = \frac{6}{2} = 3.$$

> **Quick Tip**
>
> When you encounter an indeterminate form like $\frac{0}{0}$, factorize and cancel common terms.

---

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58. A population of 1000 plants are in Hardy-Weinberg equilibrium. Two alleles R and r determine a particular trait in this population. If the number of plants with RR genotype is 640, Rr genotype is 320, and rr genotype is 40, the frequency of the r allele (in percentage) in this population is:

Correct Answer: 20

Explanation:

The frequencies of the genotypes are:

$$\text{Frequency of RR} = \frac{640}{1000} = 0.64,$$
$$\text{Frequency of Rr} = \frac{320}{1000} = 0.32,$$
$$\text{Frequency of rr} = \frac{40}{1000} = 0.04.$$

The frequency of the r allele (q) can be calculated using the formula:

$$q^2 = \text{frequency of rr} = 0.04,$$

$$q = \sqrt{0.04} = 0.2.$$

Thus, the frequency of the r allele is 20

> **Quick Tip**
>
> In Hardy-Weinberg equilibrium, the allele frequencies are determined from the homozygous recessive genotype.

---

59. If a fair coin is tossed two times, the probability that the first or the second toss will be heads is:

Correct Answer: 0.75

Explanation:

The probability of getting heads on either toss is:

$$P(\text{first head}) = \frac{1}{2}, \quad P(\text{second head}) = \frac{1}{2}.$$

Using the formula for the probability of either event occurring:

$$P(\text{first or second head}) = P(\text{first head}) + P(\text{second head}) - P(\text{both heads}),$$
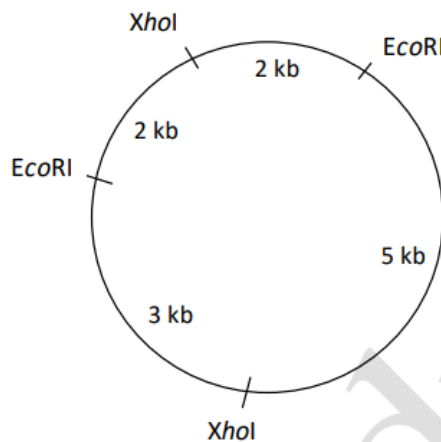
$$P(\text{both heads}) = \frac{1}{4}.$$

Thus:

$$P = \frac{1}{2} + \frac{1}{2} - \frac{1}{4} = 0.75.$$

> **Quick Tip**
>
> When calculating the probability of "either" event, subtract the overlap if events are not mutually exclusive.

---

60. The number of bands that will be visible in the gel when exposed to UV light after complete digestion of a circular plasmid with EcoRI and XhoI is:

Correct Answer: 3

Explanation:

EcoRI cuts the plasmid into two fragments (2 kb and 3 kb), and XhoI cuts it into 2 fragments (2 kb and 5 kb). The restriction map shows two EcoRI and two XhoI sites, leading to a total of three distinct bands when the plasmid is completely digested.

> **Quick Tip**
>
> Multiple restriction enzymes lead to multiple bands in gel electrophoresis, corresponding to the sizes of the fragments.