

Section 1: Reading skills and knowledge acquired during studies

Question 1

Which Italian director is best known for the 1960 film *La Dolce Vita*, a landmark of world cinema that introduced the term “paparazzi” to popular culture?

- A) Luchino Visconti
- B) Roberto Rossellini
- C) Federico Fellini
- D) Michelangelo Antonioni
- E) Vittorio De Sica

• Correct Answer: C

[Basis for the Correct Answer]

The 1960 film *La Dolce Vita* is internationally recognized as a masterpiece by the Italian director Federico Fellini. The film portrays the decadent lifestyle of Rome’s high society and is considered a milestone in the history of cinema. Furthermore, the term *paparazzi* originated from the name of a photographer character, *Paparazzo*, who appears in the film, and the word subsequently spread worldwide.

[Evaluation of the Options]

- (A), (B), (D), (E): All are major figures in Italian cinema, but *La Dolce Vita* was directed by Fellini.
 - Luchino Visconti: *The Leopard*, *Death in Venice*
 - Roberto Rossellini: *Rome, Open City*
 - Michelangelo Antonioni: *L’Avventura*
 - Vittorio De Sica: *Bicycle Thieves*

[IMAT Perspective]

Learning point: In IMAT general knowledge questions, topics related to Italian cultural history (cinema, art, literature) frequently appear. Knowing internationally influential works and figures is particularly advantageous.

Question 2

Although the European Union (EU) is primarily known as an economic and political union, it also plays a role in cultural preservation. Through programmes like Creative Europe, it funds projects that support linguistic diversity, artistic exchange, and heritage conservation. This reflects the EU’s recognition that cultural identity contributes to cohesion among member states.

The passage suggests that the EU’s cultural initiatives:

- A) Are unrelated to its political goals
- B) Aim to strengthen unity among member states
- C) Replace national cultural policies entirely
- D) Focus exclusively on economic benefits
- E) Are limited to the preservation of ancient monuments

• Correct Answer: B

[Basis for the Correct Answer]

This is an inference question asking what the passage suggests. The key sentence is: "This reflects the EU's recognition that cultural identity contributes to cohesion among member states."

The phrase cohesion among member states clearly corresponds to strengthening unity among member states. Therefore, the correct inference is that the EU's cultural initiatives aim to enhance unity.

[Evaluation of the Options]

- (A): Incorrect — the text explicitly links culture to political cohesion.
- (C): Incorrect — there is no indication that national policies are replaced.
- (D): Incorrect — the passage clearly states cultural, not purely economic, goals.
- (E): Incorrect — support includes linguistic diversity and artistic exchange, not only monuments.

[IMAT Perspective]

Learning point: In inference questions, it is essential to connect keywords in the text with synonymous or paraphrased expressions in the answer choices. Recognizing that cohesion and unity are used in the same context is crucial.

Question 3

Which novel was written by Victor Hugo and tells the story of Jean Valjean, a former prisoner trying to rebuild his life in 19th-century France?

- A) War and Peace
- B) Les Misérables
- C) Crime and Punishment
- D) Madame Bovary
- E) The Hunchback of Notre-Dame
- Correct Answer: B

[Basis for the Correct Answer]

The epic novel depicting the life of Jean Valjean, who was imprisoned for 19 years for stealing bread, is *Les Misérables*, written by Victor Hugo. The novel is set against the backdrop of 19th-century French society and is one of Hugo's most famous works.

[Evaluation of the Options]

- (A) War and Peace: Written by Tolstoy (Russian literature).
- (C) Crime and Punishment: Written by Dostoevsky (Russian literature).
- (D) Madame Bovary: Written by Flaubert (French literature).
- (E) The Hunchback of Notre-Dame: Also by Victor Hugo, but the protagonist is Quasimodo, not Jean Valjean.

[IMAT Perspective]

Learning point: Familiarity with major world literature authors and their most famous works is expected. Being able to distinguish Victor Hugo's two major novels (*Les Misérables* and *The Hunchback of Notre-Dame*) is essential.

Question 4

What was the name of the 1917 British declaration supporting a Jewish homeland in Palestine?

- A) Balfour Declaration
- B) Versailles Treaty
- C) Camp David Accords
- D) Sykes–Picot Agreement
- E) Oslo Accords

• Correct Answer: A

[Basis for the Correct Answer]

In 1917, during World War I, British Foreign Secretary Arthur Balfour sent a letter to Lord Rothschild expressing support for the establishment of a “national home” for the Jewish people in Palestine. This document is known as the Balfour Declaration and later became a major factor in Middle Eastern politics.

[Evaluation of the Options]

- (B) Versailles Treaty: Peace treaty ending World War I (1919).
- (C) Camp David Accords: Peace agreement between Egypt and Israel (1978).
- (D) Sykes–Picot Agreement: Secret agreement dividing Ottoman territories (1916).
- (E) Oslo Accords: Agreement between Israel and the PLO (1993).

[IMAT Perspective]

Learning point: Key declarations and agreements in 20th-century Middle Eastern history must be distinguished by both content and date. The Balfour Declaration, Sykes–Picot Agreement, and Hussein–McMahon Correspondence are especially high-yield topics.

Section 2: Logical reasoning and problem-solving

Question 5

Several coastal cities have implemented strict fishing limits to restore declining fish populations. In the first two years, total fish catches decreased, but by the third year, catches increased beyond pre-restriction levels. Local economies, initially hurt by the reduced catch, benefited from higher market prices due to improved fish quality and scarcity. Environmental groups point out that increased populations also help maintain marine ecosystems.

Therefore, such restrictions are a model for sustainable fisheries worldwide.

What is the main conclusion of this argument?

- A) Fishing limits can temporarily harm local economies
- B) Higher market prices improve the livelihoods of fishers
- C) Restricting fishing is an effective model for sustainable fisheries
- D) Marine ecosystems benefit from larger fish populations
- E) Sustainable fishing is important for global food supply

• Correct Answer: C

[Basis for the Correct Answer]

The main conclusion is the central claim the author wants to convey. The conjunction “Therefore” signals the conclusion.

- Premises: Fishing limits initially reduce catches, later increase them, improve economic outcomes, and protect ecosystems.
- Conclusion: “Therefore, such restrictions are a model for sustainable fisheries worldwide.”

Option (C) is a direct paraphrase of this conclusion.

[Evaluation of the Options]

- (A), (B), (D): These are supporting reasons or observations, not the main conclusion.
- (E): This is a general statement that can be inferred but is not the central claim of the passage.

[IMAT Perspective]

Learning point: When identifying conclusions, look for conclusion markers such as therefore, thus, so, consequently. These words almost always introduce the main conclusion.

Question 6

A patient needs 0.8 g of a drug per day. The drug comes in 200 mg tablets, taken in equal doses every 6 hours. A pack contains 40 tablets.

How many days will 2 packs last?

- A) 9 days
- B) 10 days
- C) 20 days
- D) 25 days
- E) 30 days

- Correct Answer: C

[Basis for the Correct Answer]

1. Convert units
 $0.8 \text{ g} = 800 \text{ mg}$
2. Tablets required per day
 $1 \text{ tablet} = 200 \text{ mg}$
 $800 \text{ mg} \div 200 \text{ mg} = 4 \text{ tablets per day}$
3. Total number of tablets
 $1 \text{ pack} = 40 \text{ tablets}$
 $2 \text{ packs} = 80 \text{ tablets}$
4. Calculate duration
 $80 \text{ tablets} \div 4 \text{ tablets/day} = 20 \text{ days}$

The “every 6 hours” detail confirms that the daily dose is divided into 4 equal doses but does not change the total daily amount.

[Evaluation of the Options]

- (A): Incorrect calculation.
- (B): Assumes only 1 pack.
- (D), (E): No mathematical basis.

[IMAT Perspective]

Learning point: Frequent mistakes come from unit conversion errors or misreading dosage frequency. Always calculate the total daily dose first.

Question 7

Sophie has two different mixtures of pineapple juice and mango juice.

- Mixture 1: 40% pineapple juice and 60% mango juice
- Mixture 2: 70% pineapple juice and 30% mango juice

Sophie wants to make 6 litres of a mixture that is 50% pineapple juice and 50% mango juice.

How much of mixture 2 does Sophie need to use?

- A) 1 litre
- B) 2 litres
- C) 3 litres
- D) 4 litres
- E) 5 litres

- Correct Answer: B

[Basis for the Correct Answer]

Let:

- x = litres of mixture 1
- y = litres of mixture 2

Equation 1 (total volume):

$$x + y = 6$$

Equation 2 (pineapple juice content):

$$0.4x + 0.7y = 3 \text{ (because 50\% of 6 litres = 3 litres)}$$

Substitute $x = 6 - y$ into equation 2:

$$0.4(6 - y) + 0.7y = 3$$

$$2.4 - 0.4y + 0.7y = 3$$

$$0.3y = 0.6$$

$$y = 2$$

So, Sophie needs 2 litres of mixture 2.

[IMAT Perspective]

Learning point: Mixture problems can be solved using simultaneous equations or weighted averages. Being comfortable with both approaches allows faster problem-solving.

Question 8

Read the sentence below. Which part of the sentence contains a meaning error?

“After winning the marathon in record time, Julia was disappointed with her performance and celebrated enthusiastically with her friends.”

- A) After winning the marathon
- B) in record time
- C) was disappointed with her performance
- D) and celebrated enthusiastically
- E) with her friends

- Correct Answer: C

[Basis for the Correct Answer]

This sentence contains a logical contradiction.

- First part: "After winning the marathon in record time" indicates an exceptionally outstanding achievement.
- Second part: It states that "Julia was disappointed with her performance and celebrated enthusiastically."

The objectively great success of "winning in record time" and the subjective evaluation of "was disappointed with her performance" usually do not coexist. In context, this creates a contradiction that does not make logical sense. Being disappointed with such an excellent result is unnatural.

[Evaluation of the Options]

- (A), (B), (D), (E): Individually logical and grammatically correct.
- (C): Creates a semantic inconsistency with the context.

[IMAT Perspective]

Learning point: Logical reasoning questions may test semantic consistency, not just grammar. Always check whether different parts of a sentence logically agree.

Question 9

A 250 g bag of mixed dried fruits lists the contents as follows:

- Apricots: 20–30%
- Figs: 10–20%
- Dates: 5–15%
- Raisins: 30–40%
- Prunes: 10–20%

All the apricots are eaten. The apricot content was at the minimum possible value consistent with the label.

What is the largest possible raisin content of the dried fruits remaining in the bag?

- A) 40%
- B) 48%
- C) 50%
- D) 57%
- E) 60%

- Correct Answer: C

[Basis for the Correct Answer]

The aim of this question is to maximize the proportion of raisins among the remaining fruits. To maximize the value of a fraction, it is necessary to maximize the numerator (the amount of raisins) and minimize the denominator (the total mass of the remaining fruits).

[Approach]

1. Determine the amount of apricots eaten: 50 g.

2. Calculate the total mass of the remaining fruits:
 $250 \text{ g} - 50 \text{ g} = 200 \text{ g}$. This becomes the denominator.
3. Maximize the numerator (the amount of raisins):
 - To maximize the amount of raisins, set their proportion to the maximum allowed value (40%).
 - Maximum amount of raisins = $250 \text{ g} \times 40\% = 100 \text{ g}$.
4. Check whether this scenario is feasible:
 - Apricots: 20% (50 g)
 - Raisins: 40% (100 g)
 - Remaining percentage = $100\% - 20\% - 40\% = 40\%$
 - Check whether the combined proportion of the remaining fruits (figs, dates, prunes) can be set to 40%.
 - Figs (10–20%), dates (5–15%), and prunes (10–20%) can indeed sum to 40% within their allowed ranges (for example: figs 15%, dates 10%, prunes 15%).
 - Therefore, having 100 g of raisins is a valid scenario.
5. Calculate the final proportion:
 - Proportion of raisins among the remaining fruits = (amount of raisins) / (total remaining fruit mass)
 - $= 100 \text{ g} / 200 \text{ g} = 0.5$
 - Converted to a percentage, this is 50%.

[IMAT Perspective]

Learning point: In problems that ask for maximum or minimum values, it is important to clearly define what you want to maximize or minimize and which variables must be maximized or minimized in order to achieve that goal.

Section 3: Biology

Question 10

During cell division, a student notices that the genetic material has condensed into visible, X-shaped structures. He wonders whether gene expression is occurring at this time.

What's the most accurate conclusion?

- A) Gene expression continues at full speed during mitosis
- B) The condensed X structures are centrioles directing microtubules
- C) These are chromosomes, and transcription is largely inactive
- D) The structures are chromatin being actively transcribed
- E) These are nucleoli, and they drive cytokinesis

• Correct Answer: C

[Basis for the Correct Answer]

- X-shaped structures observed during cell division are chromosomes, composed of two sister chromatids joined at the centromere.
- For gene expression (transcription) to occur, DNA must be in a relaxed chromatin state.

- During mitosis, chromosomes are highly condensed, preventing RNA polymerase from accessing DNA. As a result, transcription is largely inactive. Therefore, option (C) is the most accurate conclusion.

[Evaluation of the Options]

- (A): Incorrect — transcription is largely halted during mitosis.
- (B): Incorrect — centrioles are involved in spindle formation, not genetic material.
- (D): Incorrect — Condensed chromosomes are inactive, whereas relaxed chromatin is transcribed.
- (E): Incorrect — nucleoli disappear during mitosis.

[IMAT Perspective]

Learning point: Understanding how chromatin structure changes throughout the cell cycle and how this affects gene expression—especially transcription—is essential.

Question 11

What best describes the role of cholesterol in animal cell membranes?

- A) Forms pores for diffusion
 - B) Facilitates ATP production
 - C) Increases permeability to ions
 - D) Maintains membrane fluidity
 - E) Tags proteins for degradation
- Correct Answer: D

[Basis for the Correct Answer]

In animal cell membranes, cholesterol plays a key role in regulating membrane fluidity.

- At high temperatures: cholesterol stabilizes the membrane and prevents excessive fluidity.
 - At low temperatures: it prevents phospholipids from packing too tightly, maintaining fluidity.
- Thus, cholesterol acts as a fluidity buffer.

[Evaluation of the Options]

- (A): Incorrect — pores are formed by channel proteins.
- (B): Incorrect — ATP production occurs in mitochondria.
- (C): Incorrect — cholesterol generally decreases membrane permeability.
- (E): Incorrect — protein degradation tagging involves ubiquitin.

[IMAT Perspective]

Learning point: In the fluid mosaic model, knowing the specific role of each membrane component—especially cholesterol—is a high-yield topic.

Question 12

In human cells there are normally 46 chromosomes. During which stage of the cell cycle would a human cell temporarily have 92 chromosomes?

- A) G1 phase
- B) Anaphase I
- C) Anaphase II

- D) Anaphase of mitosis
E) Telophase I
• Correct Answer: D

[Basis for the Correct Answer]

Chromosome number is counted based on the number of centromeres.

- S phase: After DNA replication, during G₂ phase and prophase–metaphase of mitosis, each chromosome consists of two sister chromatids. However, because there is only one centromere per chromosome, the chromosome number remains 46.
- Anaphase of mitosis: The centromeres of each chromosome separate, and the sister chromatids become independent daughter chromosomes that move toward opposite poles. At this moment, the number of centromeres temporarily doubles, so the chromosome number within the cell becomes $46 \times 2 = 92$.
- After telophase: Once cytokinesis is completed, the two daughter cells each end up with 46 chromosomes.

[Evaluation of the Options]

- (A) G₁ phase: Before DNA replication, so the cell has 46 chromosomes.
- (B) Anaphase I (meiosis I): Homologous chromosomes separate, but sister chromatids remain joined. Therefore, 23 chromosomes move toward each pole (they are not bivalent chromosomes). In the cell as a whole, 46 chromosomes (each consisting of two sister chromatids) are in the process of separating.
- (C) Anaphase II (meiosis II): Sister chromatids separate, and the chromosome number temporarily becomes $23 \times 2 = 46$.
- (E) Telophase I (end of meiosis I): Two daughter cells are formed, each containing 23 chromosomes, with each chromosome still consisting of two sister chromatids.

[IMAT Perspective]

Learning point: It is important to be able to accurately track the changes in both chromosome number and DNA content at each stage of mitosis and meiosis. In particular, make sure you clearly understand how chromosomes are counted (i.e., by the number of centromeres).

Question 13

Which polysaccharide is the main energy storage carbohydrate in plants?

- A) Glycogen
B) Sucrose
C) Amylopectin
D) Starch
E) Cellulose
• Correct Answer: D

[Basis for the Correct Answer]

Plants store energy primarily as starch, a glucose polymer composed of amylose and amylopectin. Glucose produced during photosynthesis is converted into starch and stored in chloroplasts and storage organs such as roots and seeds.

[Evaluation of the Options]

- (A) Glycogen: The main energy-storage polysaccharide in animals and fungi.
- (B) Sucrose: A disaccharide. It is the primary form in which photosynthetic products are transported within plants, but it is not the main storage polysaccharide.
- (C) Amylopectin: One of the components of starch, but the broader and more appropriate term here is “starch.”
- (E) Cellulose: A structural polysaccharide that makes up the plant cell wall; its primary role is not energy storage.

[IMAT Perspective]

For the major polysaccharides—starch, glycogen, and cellulose—it is important to learn them together by linking the organism in which they are found (plant or animal), their role (storage or structural), and their monomer (glucose).

Question 14

During oxidative phosphorylation, the energy from the electron transport chain is used to:

- A) Directly phosphorylate ADP to ATP
- B) Pump protons into the mitochondrial matrix
- C) Pump protons into the intermembrane space
- D) Split glucose into pyruvate
- E) Reduce NAD^+ to NADH

• Correct Answer: C

[Basis for the Correct Answer]

In oxidative phosphorylation, high-energy electrons supplied from NADH and FADH_2 flow through the electron transport chain (ETC). Using the energy of these electrons, protein complexes of the electron transport chain actively transport protons (H^+) from the mitochondrial matrix to the intermembrane space. As a result, an electrochemical gradient of protons is formed in the intermembrane space, and this gradient becomes the driving force for ATP synthesis.

[Examination of the Options]

- (A) Directly phosphorylate ADP to ATP: This is an explanation of substrate-level phosphorylation. Oxidative phosphorylation is an indirect process.
- (B) Pump protons into the mitochondrial matrix: Protons leave the matrix. The direction is the opposite.
- (D) Split glucose into pyruvate: This is an explanation of glycolysis.
- (E) Reduce NAD^+ to NADH: This is a reaction that occurs in glycolysis and the citric acid cycle. In the electron transport chain, NADH is oxidized.

[IMAT Perspective]

Learning point: It is important to accurately understand the mechanism of chemiosmosis in cellular respiration. In particular, questions that ask about directionality—“from where to where” protons are pumped, and “where” the proton gradient is formed—appear frequently.

Question 15

In a dipeptide, the peptide bond is formed between:

- A) The R groups of two amino acids
- B) The amino group of one and the carboxyl group of the other
- C) Two carboxyl groups
- D) Two amino groups
- E) A hydroxyl group and a carboxyl group

• Correct Answer: B

[Basis for the Correct Answer]

A peptide bond is an amide bond formed when two amino acids join together via a dehydration condensation reaction. Specifically, it is formed between the carboxyl group (-COOH) of one amino acid and the amino group (-NH₂) of the other amino acid. At this time, one water molecule is removed.

[Examination of the Options]

- (A) The R groups...: R groups (side chains) can form disulfide bonds and the like, but they are not involved in peptide bonds of the main chain.
- (C), (D): A peptide bond is not formed between the same functional groups (between carboxyl groups or between amino groups).
- (E) A hydroxyl group and a carboxyl group: This is related to the formation of an ester bond.

[IMAT Perspective]

Learning point: Accurately understanding the basic structure of amino acids (amino group, carboxyl group, α carbon, side chain R group) and the mechanism of peptide bond formation is fundamental to protein chemistry.

Question 16

In aerobic respiration, oxidation of NADH yields more ATP than oxidation of FADH₂ because:

- A) NADH donates electrons to Complex I, while FADH₂ donates them later in the chain
- B) NADH is produced in greater amounts than FADH₂
- C) FADH₂ is used mainly in anaerobic respiration
- D) NADH has a higher energy content due to more hydrogen atoms
- E) FADH₂ cannot be oxidized in mitochondria

• Correct Answer: A

[Basis for the Correct Answer]

The reason there is a difference in the amount of ATP produced by NADH and FADH₂ is that they supply electrons at different points in the electron transport chain (ETC).

- NADH: It supplies electrons to Complex I, which is the first complex of the electron transport chain.
- FADH₂: It supplies electrons to Complex II. Complex I functions as a proton pump, but Complex II does not. Therefore, electrons derived from NADH contribute to pumping more protons into the intermembrane space than electrons derived from FADH₂. As a result of forming a larger proton gradient, the amount of ATP produced

per NADH molecule (about 2.5 ATP) becomes greater than per FADH₂ molecule (about 1.5 ATP).

[Examination of the Options]

- (B) NADH is produced in greater amounts....: This is true, but it is not the “reason” there is a difference in ATP yield.
- (C) FADH₂ is used mainly in anaerobic respiration: FADH₂ is used in aerobic respiration.
- (D) ...due to more hydrogen atoms: The difference in energy content is a result and is not an explanation of the mechanism.
- (E) FADH₂ cannot be oxidized in mitochondria: FADH₂ is oxidized in mitochondria.

[IMAT Perspective]

Learning point: Detailed knowledge is required regarding the roles of each complex in the electron transport chain and where NADH and FADH₂ donate their electrons. It is important to understand the fundamental reason for the difference in ATP yield.

Question 17

Which of the following steps is NOT typically part of recombinant DNA technology?

- A) Cutting DNA with restriction endonucleases
- B) Ligating DNA fragments with DNA ligase
- C) Introducing recombinant DNA into a host cell
- D) Amplifying DNA using PCR
- E) Breaking phosphodiester bonds using RNA polymerase

• Correct Answer: E

[Basis for the Correct Answer]

The basic steps of recombinant DNA technology are as follows.

1. Cut the target DNA and the vector (such as a plasmid) using a restriction endonuclease (A).
2. Insert the cut DNA fragment into the vector and join it (ligation) using DNA ligase (B).
3. Introduce (transform) the constructed recombinant DNA into a host cell such as E. coli (C).
4. PCR may also be used to amplify the target DNA fragment (D).

RNA polymerase is an enzyme involved in transcription that synthesizes RNA using DNA as a template, and it does not have the role of cutting DNA phosphodiester bonds. Therefore, (E) is not a typical step of recombinant DNA technology.

[IMAT Perspective]

Learning point: It is important to accurately understand the main enzymes used in recombinant DNA technology (restriction enzymes, DNA ligase) and their roles. Also, clearly distinguish their roles from those of other major enzymes (DNA polymerase, RNA polymerase).

Question 18

Which of the following best describes the role of mutations in evolution?

- A) Mutations always decrease an organism's fitness
- B) Mutations create new genetic variation, which can be acted upon by evolutionary processes
- C) Mutations are the primary cause of genetic drift
- D) Mutations occur only in response to environmental changes
- E) Mutations only occur in somatic cells

• Correct Answer: B

[Basis for the Correct Answer]

The driving force of evolution is genetic variation, and its ultimate source is mutation. Mutations introduce new alleles into an existing gene pool. When evolutionary processes such as natural selection act on this diverse genetic variation, the genetic composition of a population changes over time. Therefore, (B) explains the evolutionary role of mutations most well.

[Examination of the Options]

- (A) ...always decrease...fitness: Mutations can be harmful, but they can also be neutral, or in some cases beneficial.
- (C) ...primary cause of genetic drift: Genetic drift is a phenomenon in which allele frequencies fluctuate due to chance, and it is not mutation itself.
- (D) ...occur only in response to environmental changes: Mutations occur basically at random.
- (E) ...only occur in somatic cells: Mutations that occur in somatic cells are not inherited by the next generation. What affects evolution are mutations that occur in the germline.

[IMAT Perspective]

Learning point: It is important to correctly understand the role of mutations in the modern evolutionary synthesis. Mutations supply the “raw material for evolution,” and they themselves have no directionality—this point is important.

Question 19

Which molecule is regenerated at the end of the Calvin cycle to allow the fixation of additional CO₂?

- A) 3-phosphoglycerate (3-PGA)
- B) Glyceraldehyde-3-phosphate (G3P)
- C) Ribulose-1,5-bisphosphate (RuBP)
- D) NADP⁺
- E) ATP

• Correct Answer: C

[Basis for the Correct Answer]

The Calvin cycle is a cyclic reaction that fixes CO₂ and synthesizes sugars.

1. Carbon fixation: CO₂ is fixed to a 5-carbon sugar called ribulose-1,5-bisphosphate (RuBP).

2. Reduction: Using ATP and NADPH, the products are reduced and G3P (a precursor of sugars) is produced.
3. Regeneration: Some of the G3P leaves the cycle and is used for sugar synthesis, but the remaining G3P is regenerated into RuBP using ATP. By using this regenerated RuBP to fix the next CO₂ molecule, the cycle continues to circulate.

[Examination of the Options]

- (A) 3-PGA: An intermediate produced immediately after CO₂ fixation.
- (B) G3P: Produced in the reduction stage, and part of it is used for regeneration of RuBP.
- (D) NADP⁺, (E) ATP: These are energy and reducing power consumed during the RuBP regeneration stage and are not molecules that are regenerated.

[IMAT Perspective]

Learning point: It is important to understand the three major stages of the Calvin cycle (carbon fixation, reduction, RuBP regeneration), the key substances in each stage (CO₂, RuBP, 3-PGA, G3P), and the inflow and outflow of energy (ATP, NADPH).

Question 20

In a population of wild rabbits living in a grassland... Which of the following statements best explains the observed changes in both populations?

- A) The wild population shows natural selection for the B allele, while the farmed population shows artificial selection for the b allele.
- B) The wild population shows artificial selection for the B allele, while the farmed population shows natural selection for the b allele.
- C) Both populations show natural selection, but for different alleles.
- D) Both populations show artificial selection, but for different alleles.
- E) The change in allele frequencies is purely due to random genetic drift in both populations.

• Correct Answer: A

[Basis for the Correct Answer]

This problem identifies the evolutionary mechanisms occurring in two different populations.

- Wild rabbit population:
 - The environment (short winters, long summers) acts in a way that benefits the survival and reproduction of individuals with a specific trait (brown fur B) (camouflage from predators).
 - A process in which the environment serves as a selection pressure and allele frequencies change is called natural selection (natural selection).
- Farmed rabbit population:
 - Humans (the farmer) intentionally choose and breed individuals with a specific trait (white fur b).
 - The process in which humans select specific traits for breeding livestock or crops is called artificial selection (artificial selection).

Therefore, it is most appropriate to explain that natural selection for the B allele is occurring in the wild population, and artificial selection for the b allele is occurring in the farmed population.

[IMAT Perspective]

Learning point: It is important to clearly understand the definitions of natural selection and artificial selection, and their difference (whether the selection pressure is the natural environment or humans).

Question 21

During skeletal muscle contraction, which event directly exposes the myosin-binding sites on actin filaments?

- A) ATP hydrolysis by myosin heads
- B) Release of calcium ions from the sarcoplasmic reticulum
- C) Binding of calcium to troponin
- D) Sliding of actin filaments past myosin filaments
- E) Depolarization of the sarcolemma

• Correct Answer: C

[Basis for the Correct Answer]

The regulatory mechanism of muscle contraction proceeds in the following steps.

1. Due to stimulation from a nerve, calcium ions (Ca^{2+}) are released from the sarcoplasmic reticulum (B).
2. The released Ca^{2+} binds to troponin, a regulatory protein on the actin filament (C).
3. This binding causes a conformational change in troponin, and along with it, another regulatory protein, tropomyosin, moves.
4. When tropomyosin moves, the myosin-binding sites on actin that had been covered up until then are exposed.

Therefore, the event that “directly” exposes the myosin-binding sites is (C), “binding of calcium to troponin.”

[Examination of the Options]

- (A) ATP hydrolysis...: ATP hydrolysis occurs to bring the myosin head into a high-energy state, but it is not directly involved in exposing the binding sites.
- (B) Release of calcium ions...: Calcium release is an important event that is a prerequisite for step (C), but it is not the “direct” cause.
- (D) Sliding of actin filaments...: This is the result that occurs “after” the binding sites have been exposed.
- (E) Depolarization of the sarcolemma: Depolarization of the muscle cell membrane is the trigger that causes calcium release in (B).

[IMAT Perspective]

Learning point: It is important to accurately understand, step by step, the molecular mechanism of muscle contraction (sliding filament theory) and the role of calcium ions that trigger it.

Question 22

Which event directly causes the semilunar valves to close during the cardiac cycle?

- A) Atrial contraction raises atrial pressure above ventricular pressure
- B) Ventricular pressure falls below arterial pressure

- C) Ventricular pressure rises above atrial pressure
- D) Atrial pressure falls below ventricular pressure
- E) Arterial pressure rises above atrial pressure

• Correct Answer: B

[Basis for the Correct Answer]

The semilunar valves (collective term for the aortic valve and pulmonary valve) are located between the ventricles and the arteries (the aorta and pulmonary artery). These valves prevent blood from flowing back from the arteries into the ventricles.

- When the valves open: When the ventricles contract and ventricular pressure exceeds arterial pressure, the valves are pushed open and blood is ejected into the arteries.
- When the valves close: When ventricular contraction ends and relaxation begins, ventricular pressure falls below arterial pressure. Then, the force of the blood in the arteries attempting to flow back toward the ventricles pushes the valves back and closes them. Therefore, the direct cause of closing the semilunar valves is (B), “ventricular pressure falls below arterial pressure.”

[Examination of the Options]

- (A), D): The relationship between atrial pressure and ventricular pressure is involved in opening and closing of the atrioventricular valves (mitral valve, tricuspid valve).
- (C): When ventricular pressure exceeds atrial pressure, the atrioventricular valves close.
- (E): Arterial pressure being higher than atrial pressure is a normal state and is not the direct cause of valve movement.

[IMAT Perspective]

Learning point: It is extremely important to understand the opening/closing timing of the four valves in the cardiac cycle (mitral valve, tricuspid valve, aortic valve, pulmonary valve) and the relationship with pressure changes in each chamber and artery that cause them, using diagrams (such as the Wiggers diagram).

Question 23

A doctor taps below a patient's kneecap, triggering the knee-jerk reflex. Which of the following is NOT involved in the reflex arc?

- A) Sensory neuron
- B) Motor neuron
- C) Interneuron in the spinal cord
- D) Brain cortex
- E) Muscle spindle receptor

• Correct Answer: D

[Basis for the Correct Answer]

The knee-jerk reflex (knee-jerk reflex) is a stretch reflex completed at the spinal cord level and does not involve conscious thought.

• Pathway of the reflex arc (Reflex arc):

1. When the patellar tendon is tapped, the quadriceps muscle is stretched.

2. The muscle spindle receptor (Muscle spindle receptor) (E) detects the stretch.
3. The sensory neuron (Sensory neuron) (A) sends a signal to the spinal cord.
4. In the spinal cord, the sensory neuron forms a direct synapse with the motor neuron (Motor neuron) (B) (a monosynaptic reflex).
5. The motor neuron causes the quadriceps to contract, and the leg kicks upward.
 - At the same time, signals are also sent via an interneuron (Interneuron) (C) to relax the antagonist muscle, the hamstrings. In this process, the brain cortex (Brain cortex), which controls thinking and voluntary movement, is not involved.

[Examination of the Options]

• (A), (B), (C), (E): These are all elements that constitute the reflex arc of the knee-jerk reflex.

[IMAT Perspective]

Learning point: It is important to understand the basic concept that a reflex is an unconscious response and is processed in the spinal cord or brainstem without involving the cerebrum.

Question 24

Which of the following statements about cell theory and cell types are correct?

1. All living organisms are composed of one or more cells
2. Eukaryotic cells lack a defined nucleus
3. Cells arise from non-living organic molecules
4. Bacteria and archaea are examples of prokaryotic organisms
5. Prokaryotic cells do not contain membrane-bound organelles

A) 1, 4, and 5 only B) 1 and 3 only C) 2, 3, and 4 only D) 1, 2, and 5 only E) All statements are correct

• Correct Answer: A

[Basis for the Correct Answer]

Determine whether each statement is true or false.

1. All living organisms are composed of one or more cells: True. This is one of the basic principles of cell theory.
2. Eukaryotic cells lack a defined nucleus: False. Having a defined nucleus is the definition of a eukaryotic cell (eukaryotic cell).
3. Cells arise from non-living organic molecules: False. According to cell theory, all cells arise from pre-existing cells (rejection of spontaneous generation).
4. Bacteria and archaea are examples of prokaryotic organisms: True. Organisms are broadly classified into prokaryotes (bacteria, archaea) and eukaryotes.
5. Prokaryotic cells do not contain membrane-bound organelles: True. Prokaryotic cells do not have membrane-bound organelles such as mitochondria or the Golgi apparatus.

Therefore, the correct statements are 1, 4, and 5.

[IMAT Perspective]

Learning point: You must accurately memorize the three pillars of cell theory (1) all

organisms are composed of cells, (2) the cell is the basic unit of life, (3) all cells arise from pre-existing cells) and the fundamental differences between eukaryotic and prokaryotic cells.

Question 25

Which of the following occurs in eukaryotic but not prokaryotic transcription?

- A) Addition of a 5' cap
- B) Use of RNA polymerase
- C) Complementary base pairing
- D) Use of a promoter sequence
- E) Elongation in the 5'→3' direction

• Correct Answer: A

[Basis for the Correct Answer]

Eukaryotic transcription involves more complex post-transcriptional processing (RNA processing) compared to prokaryotes. One of these processes is adding a special nucleotide structure called a 5' cap to the 5' end of the transcribed pre-mRNA. This 5' cap protects mRNA from degradation and helps transport it from the nucleus to the cytoplasm and bind to ribosomes. This process does not exist in prokaryotes.

[Examination of the Options]

- (B), (C), (D), (E): These are basic elements common to both eukaryotes and prokaryotes in the process of transcription.

[IMAT Perspective]

Learning point: Differences in transcription and translation between eukaryotes and prokaryotes are a frequently tested theme. In particular, be sure to master eukaryote-specific RNA processing (5' cap, poly-A tail, splicing).

Question 26

In a dihybrid cross ($AaBb \times AaBb$), what proportion of offspring are expected to be homozygous recessive for both traits?

- A) $1/4$
- B) $1/8$
- C) $1/16$
- D) $3/16$
- E) $9/16$

• Correct Answer: C

[Basis for the Correct Answer]

In a dihybrid cross that follows the law of independent assortment, you can consider the two traits separately and multiply the probabilities.

1. Segregation ratio for trait A:
 - From $Aa \times Aa$, the probability of aa is $1/4$.
2. Segregation ratio for trait B:
 - From $Bb \times Bb$, the probability of bb is $1/4$.

3. Probability of being homozygous recessive for both traits (aabb):
 - By independent assortment, multiply the probabilities.
 - $P(aabb) = P(aa) \times P(bb) = (1/4) \times (1/4) = 1/16$

[IMAT Perspective]

Learning point: The phenotypic ratio (9:3:3:1) from $AaBb \times AaBb$ is well known, but when asked for the probability of a specific genotype, it is faster and more reliable to treat each locus independently and multiply probabilities.

Question 27

In a population, 16% of individuals have a recessive phenotype for a trait controlled by a single gene. What is the frequency of the dominant allele?

- A) 0.16
- B) 0.4
- C) 0.6
- D) 0.84
- E) 0.8

• Correct Answer: C

[Basis for the Correct Answer]

This problem is solved using the Hardy–Weinberg principle.

- Let the frequency of the dominant allele be p and the frequency of the recessive allele be q , then $p + q = 1$.
- Genotype frequencies are p^2 (AA), $2pq$ (Aa), and q^2 (aa).
 1. Find q from the recessive phenotype frequency:
 - Only individuals who are homozygous recessive (aa) show the recessive phenotype.
 - Recessive phenotype frequency = $q^2 = 16\% = 0.16$
 - Recessive allele frequency $q = \sqrt{0.16} = 0.4$
 2. Find p using $p + q = 1$:
 - Dominant allele frequency $p = 1 - q = 1 - 0.4 = 0.6$

[Examination of the Options]

- (A) 0.16: This is the recessive phenotype frequency (q^2).
- (B) 0.4: This is the recessive allele frequency (q).
- (D) 0.84: This is the dominant phenotype frequency ($1 - 0.16 = 0.84$).

[IMAT Perspective]

Learning point: Calculation problems involving Hardy–Weinberg are frequent. It is important to accurately understand that p and q represent allele frequencies, and p^2 , $2pq$, and q^2 represent genotype frequencies, and to determine which type of information is given in the problem.

Question 28

Below is a table showing the genetic code, the corresponding mRNA codon, and the anticodon:

| Genetic Code | Codon (mRNA) | Anticodon |
|--------------|--------------|-----------|
| ATG | ATG | UAC |
| AUG | AUG | UAC |
| UUC | UUC | AAU |

| According to the table above, what should be the nucleotide sequence in the non-template strand of DNA?

- A) ATG AAG TAC
- B) TAC TTG ATG
- C) TAC AAG TAC
- D) ATG TAC AAG
- E) TAC AAG ATG

• Correct Answer: A

[Basis for the Correct Answer]

1. mRNA sequence: AUG AAG UAC
2. Relationship to the DNA non-template strand:
 - The DNA non-template strand (also called the coding strand) is very similar to the mRNA sequence, and it becomes the same sequence with only U (uracil) replaced by T (thymine).
3. Sequence conversion:
 - AUG → ATG
 - AAG → AAG
 - UAC → TAC
4. Conclusion:
 - Therefore, the sequence of the DNA non-template strand is ATG AAG TAC.

[IMAT Perspective]

Learning point: It is important to fully understand the relationships of complementarity and directionality among the DNA template strand, non-template strand, mRNA, and the tRNA anticodon.

Question 29

Which cytoskeletal component is primarily responsible for maintaining cell shape, resisting tension, and anchoring organelles in place?

- A) Actin filaments
- B) Intermediate filaments
- C) Microtubules
- D) Centrioles
- E) Flagella

• Correct Answer: B

[Basis for the Correct Answer]

The three components of the cytoskeleton each have different roles.

- Intermediate filaments (Intermediate filaments): They are composed of keratin, lamin, and others, and have a very tough, rope-like structure. Their main roles are to provide mechanical strength to the cell, resist tension, maintain cell shape, and anchor organelles such as the nucleus in their proper positions.

[Examination of the Options]

- (A) Actin filaments (microfilaments): Mainly involved in cell movement (amoeboid movement, muscle contraction) and cytokinesis.

- (C) Microtubules: Involved as tracks for intracellular transport, also in spindle formation during cell division, and in movement of flagella and cilia.
- (D) Centrioles: The microtubule organizing center.
- (E) Flagella: Motility organelles made of microtubules.

[IMAT Perspective]

Learning point: It is important to accurately memorize, while comparing, the structure and major functions of the three cytoskeletal filament types (microfilaments, intermediate filaments, microtubules).

Question 30

Sunny's mother visits the internal medicine outpatient clinic for a check-up... Which of the above could be possible causes?

1. Insufficient insulin secretion from the pancreas
 2. Failure of glucose reabsorption in the kidney
 3. Inadequate stimulation of the pancreas by the pituitary gland
 4. Dysfunction of insulin-sensitive receptors in the cell membrane
- A) 1, 2 B) 2, 3 C) 1, 2, 4 D) 1, 3, 4 E) 2, 3, 4
- Correct Answer: C

[Basis for the Correct Answer]

Examine possible causes of an excessive amount of glucose being excreted in urine (glucosuria).

1. Insufficient insulin secretion from the pancreas: Possible. If insulin secretion is insufficient, blood glucose rises (hyperglycemia). When blood glucose exceeds the threshold of the kidney's reabsorption capacity, glucose is excreted in urine. This is mainly the cause of type 1 diabetes.
2. Failure of glucose reabsorption in the kidney: Possible. Even if blood glucose is normal, if there is impairment in glucose reabsorption in the proximal tubules of the kidney, glucose is excreted in urine (renal glucosuria).
3. Inadequate stimulation of the pancreas by the pituitary gland: Unlikely. The main regulating factor for insulin secretion is blood glucose itself, not direct stimulation from the pituitary gland (pituitary gland).
4. Dysfunction of insulin-sensitive receptors in the cell membrane: Possible. Even if insulin is secreted, if receptors on target cells do not function properly (insulin resistance), cells cannot take up glucose and hyperglycemia occurs. This is mainly the cause of type 2 diabetes.

Therefore, the possible causes are 1, 2, and 4.

[IMAT Perspective]

Learning point: It is important to understand the mechanism of blood glucose regulation and the pathologies in which it breaks down (diabetes) from multiple angles. Not only the action of insulin but also the role of glucose reabsorption in the kidney must be understood.

Question 31

A scientist studies glucose uptake in muscle cells. She finds that glucose enters the cell

down its concentration gradient but only when a specific membrane protein is functional. Which of the following best describes this type of transport?

- A) Simple diffusion
- B) Facilitated diffusion
- C) Primary active transport
- D) Secondary active transport
- E) Osmosis

• Correct Answer: B

[Basis for the Correct Answer]

This transport has two important characteristics.

1. It follows the concentration gradient (down its concentration gradient): The substance moves from higher concentration to lower concentration and is passive transport that does not require energy (ATP).
2. It requires a specific membrane protein (only when a specific membrane protein is functional): Assistance of a protein is needed for transport.

Passive transport that follows the concentration gradient but requires help from membrane proteins is called facilitated diffusion (Facilitated diffusion). Uptake of glucose and amino acids into cells is a typical example of this type.

[Examination of the Options]

- (A) Simple diffusion: Transport that does not require membrane proteins and passes directly through the lipid bilayer (e.g., O₂, CO₂).
- (C), (D) Active transport: A process that transports substances against the concentration gradient and requires energy.
- (E) Osmosis: A diffusion phenomenon in which water passes through a semipermeable membrane.

[IMAT Perspective]

Learning point: For each type of substance transport across the cell membrane (simple diffusion, facilitated diffusion, active transport), it is important to organize understanding along two axes: “whether it follows or goes against the concentration gradient” and “whether it requires membrane proteins.”

Question 32

Which of the following best describes the semiconservative model of DNA replication?

- A) Each daughter DNA molecule consists of two newly synthesized strands.
- B) Each daughter DNA molecule consists of one parental strand and one newly synthesized strand.
- C) The parental DNA molecule remains intact, and an entirely new DNA molecule is synthesized alongside it.
- D) Each daughter DNA molecule consists of random segments of old and new DNA interspersed along both strands.
- E) Both strands of the parental DNA are degraded and replaced by newly synthesized strands.

• Correct Answer: B

[Basis for the Correct Answer]

The semiconservative model of DNA replication (semiconservative model) is a model in which the two daughter DNA molecules after replication are each composed of one parental strand (parental strand) and one newly synthesized strand (newly synthesized strand). The original DNA double helix unwinds, and new complementary strands are made using each strand as a template. Option (B) accurately describes this model.

[Examination of the Options]

- (A): This is part of the dispersive replication model, but not a complete description.
- (C): This is the conservative replication model.
- (D): This is the dispersive replication model.
- (E): Parental strands are not degraded; they are preserved as templates.

[IMAT Perspective]

Learning point: It is important to understand the three hypothetical models of DNA replication (conservative, semiconservative, dispersive) and the background of how the semiconservative model was proven by the Meselson–Stahl experiment.

Section 4: Chemistry

Question 33

Which compound contains an ester functional group?

- A) $\text{CH}_3\text{CH}_2\text{OH}$
- B) $\text{CH}_3\text{COOCH}_3$
- C) CH_3CONH_2
- D) $\text{CH}_3\text{CH}_2\text{NH}_2$
- E) $\text{CH}_3\text{CH}_2\text{CH}_3$

• Correct Answer: B

[Basis for the Correct Answer]

An ester (Ester) functional group is characterized by the structure $-\text{COO}-$ in which a carbonyl group ($\text{C}=\text{O}$) and an ether-like oxygen atom are adjacent.

- (B) $\text{CH}_3\text{COOCH}_3$ (methyl acetate): It contains this structure ($-\text{COOR}-$) and is an ester.

[Examination of the Options]

- (A) $\text{CH}_3\text{CH}_2\text{OH}$ (ethanol): It is an alcohol with a hydroxyl group ($-\text{OH}$).
- (C) CH_3CONH_2 (acetamide): It is an amide with an amide bond ($-\text{CONH}-$).
- (D) $\text{CH}_3\text{CH}_2\text{NH}_2$ (ethylamine): It is an amine with an amino group ($-\text{NH}_2$).
- (E) $\text{CH}_3\text{CH}_2\text{CH}_3$ (propane): It is an alkane with no functional group.

[IMAT Perspective]

Learning point: Accurately memorizing the names and structures of major functional groups is the very foundation of organic chemistry.

Question 34

What is the oxidation number of hydrogen in sodium hydride (NaH)?

- A) +1
- B) 0
- C) -1
- D) +2
- E) -2

• Correct Answer: C

[Basis for the Correct Answer]

There are some exceptions to the rules for determining oxidation numbers.

- Rule: The oxidation number of hydrogen (H) is +1 in most compounds.
- Exception: In metal hydrides (metal hydride), hydrogen has an oxidation number of -1.

Sodium hydride (NaH) is a compound of sodium (Na), an alkali metal, and hydrogen. Since the oxidation number of the metal Na is always +1, for the total charge of the compound to be 0, the oxidation number of H must be -1.

[Examination of the Options]

- (A) +1: This is the general oxidation number of hydrogen in compounds with nonmetals.
- (B) 0: This is the oxidation number in the elemental form.

[IMAT Perspective]

Learning point: It is important to memorize the basic rules of oxidation numbers together with important exceptions such as oxygen in peroxides (-1) and hydrogen in metal hydrides (-1).

Question 35

Which metal oxide will produce a strong base when dissolved in water?

- A) Al_2O_3
- B) CO_2
- C) K_2O
- D) SO_3
- E) ZnO

• Correct Answer: C

[Basis for the Correct Answer]

Strong bases (strong base) are produced by oxides of alkali metals (Group 1) or alkaline earth metals (Group 2, excluding Be and Mg).

- (C) K_2O (potassium oxide): Potassium (K) is an alkali metal. It reacts vigorously with water to produce potassium hydroxide (KOH), which is a strong base.
 - Reaction equation: $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{KOH}$

[Examination of the Options]

- (A) Al_2O_3 , (E) ZnO : These do not dissolve well in water, but they are amphoteric oxides that react with both acids and bases.

- (B) CO_2 , (D) SO_3 : These are nonmetal oxides that react with water to produce acids (carbonic acid H_2CO_3 and sulfuric acid H_2SO_4 , respectively), so they are acidic oxides.

[IMAT Perspective]

Learning point: It is important to understand the relationship between periodic table position and oxide properties (metals \rightarrow basic, nonmetals \rightarrow acidic, intermediate \rightarrow amphoteric). In particular, remember that oxides of Group 1 and Group 2 metals produce strong bases.

Question 36

A sealed container holds 1.00 mol of an ideal gas at a temperature of 300 K and pressure of 2.00 atm. What is the volume of the gas? (Use $R = 0.0821 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$)

- A) 10.2 L
- B) 11.4 L
- C) 12.3 L
- D) 13.8 L
- E) 15.6 L

• Correct Answer: C

[Basis for the Correct Answer]

Using the ideal gas equation $PV = nRT$, calculate the volume V .

- Organize the given values:
 - Pressure $P = 2.00 \text{ atm}$
 - Amount of substance $n = 1.00 \text{ mol}$
 - Gas constant $R = 0.0821 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$
 - Temperature $T = 300 \text{ K}$
- Solve the equation for V :
 - $V = (nRT) / P$
- Substitute the values and calculate:
 - $V = (1.00 \times 0.0821 \times 300) / 2.00$
 - $V = (0.0821 \times 300) / 2$
 - $V = 24.63 / 2 = 12.315 \text{ L}$

The option closest to 12.315 L is (C) 12.3 L.

[IMAT Perspective]

Learning point: The ideal gas equation is fundamental for gas calculations. Memorize the formula, and use the correct units for pressure, volume, and temperature consistent with the given gas constant R .

Question 37

A student dissolves 4.90 g of NaCl ($M = 58.5 \text{ g/mol}$) in 250 cm^3 of water to prepare a solution. What is the concentration of the solution in mol/dm^3 ?

- A) $0.20 \text{ mol}/\text{dm}^3$
- B) $0.25 \text{ mol}/\text{dm}^3$
- C) $0.30 \text{ mol}/\text{dm}^3$
- D) $0.34 \text{ mol}/\text{dm}^3$

E) 0.40 mol/dm^3

• Correct Answer: D

[Basis for the Correct Answer]

1. Unit conversion:
 - To find molar concentration (mol/dm^3), the volume must be converted to dm^3 .
 - $1 \text{ dm}^3 = 1 \text{ L} = 1000 \text{ cm}^3$
 - Therefore, $250 \text{ cm}^3 = 0.250 \text{ dm}^3$
 2. Calculate the amount of NaCl (moles):
 - Moles = mass / molar mass = $4.90 \text{ g} / 58.5 \text{ g/mol} \approx 0.08376 \text{ mol}$
 3. Calculate the molar concentration:
 - Molar concentration = moles / volume (dm^3)
 - Molar concentration = $0.08376 \text{ mol} / 0.250 \text{ dm}^3 \approx 0.335 \text{ mol/dm}^3$
- The option closest to 0.335 mol/dm^3 is (D) 0.34 mol/dm^3 .

[IMAT Perspective]

Learning point: It is important to become familiar with the volume unit dm^3 (cubic decimeter). Remember the relationship $1 \text{ dm}^3 = 1 \text{ L} = 1000 \text{ cm}^3 = 1000 \text{ mL}$.

Question 38

Which ion has the largest radius among the following?

- A) O^{2-}
- B) Mg^{2+}
- C) Al^{3+}
- D) Na^+
- E) F^-

• Correct Answer: A

[Basis for the Correct Answer]

The listed ions (O^{2-} , F^- , Na^+ , Mg^{2+} , Al^{3+}) are all isoelectronic ions with the same electron configuration ($1s^2 2s^2 2p^6$).

When comparing radii of isoelectronic ions, the atomic number (number of protons) is the decisive factor.

- Since the electron configuration is the same, the number of electron shells is the same.
- The larger the atomic number, the larger the positive charge of the nucleus becomes, and it attracts electrons more strongly toward the nucleus.
- As a result, the ionic radius becomes smaller.

The number of protons for each ion is as follows.

- O^{2-} : 8
- F^- : 9
- Na^+ : 11
- Mg^{2+} : 12
- Al^{3+} : 13

Because O^{2-} has the fewest protons, it attracts electrons the most weakly, and therefore it has the largest ionic radius.

[IMAT Perspective]

Learning point: When comparing ionic radii, the procedure is: (1) first compare the number of electron shells, (2) if the number of shells is the same, check whether they are isoelectronic ions, and (3) if they are isoelectronic, compare by atomic number (number of protons). It is important to understand this procedure.

Question 39

Which of the following best explains why solid ionic compounds are brittle?

- A) Ions are mobile and easily shift positions.
- B) The electrostatic attraction allows flexibility.
- C) Layers of ions shift and like charges repel, causing fracture.
- D) Covalent bonds within the lattice are weak.
- E) Electrons move freely, weakening the structure.

• Correct Answer: C

[Basis for the Correct Answer]

Ionic crystals have a hard structure in which cations and anions are arranged regularly due to electrostatic attraction. When a strong force is applied from outside, layers of ions shift. When the layers shift, the positions of adjacent cations and anions change, and like charges such as cation–cation or anion–anion become adjacent. This produces a strong electrostatic repulsion, and the crystal easily splits along certain planes (cleavage) and is destroyed. This property is brittleness.

[Examination of the Options]

- (A) Ions are mobile...: In the solid state, ions are fixed and cannot move.
- (B) ...allows flexibility: Electrostatic attraction is strong, and there is no flexibility (malleability/ductility).
- (D) Covalent bonds...: This is ionic bonding, not covalent bonding.
- (E) Electrons move freely...: This is a feature of metallic bonding.

[IMAT Perspective]

Learning point: It is important to understand the characteristics of ionic bonds, covalent bonds, and metallic bonds (hardness, melting point, malleability/ductility, electrical conductivity, etc.) by relating them to their bonding styles while comparing them.

Question 40

The graph below shows the boiling points of the hydrogen halides: HF, HCl, HBr, and HI.

| Hydrogen Halide | Boiling Points (°C) |

| HF | +19°C |

| HCl | -85°C |

| HBr | -67°C |

| HI | -35°C |

Which of the following best explains why HF has a significantly higher boiling point than the other hydrogen halides?

- A) HF has a much larger molar mass, increasing London dispersion forces.
- B) HF molecules form strong hydrogen bonds, unlike the others.

- C) HF is a strong acid and thus harder to boil.
 D) The H-F bond is weaker than the H-Cl bond, requiring more energy to break.
 E) HF has more electrons, increasing van der Waals forces.
- Correct Answer: B

[Basis for the Correct Answer]

Boiling point reflects the strength of intermolecular forces.

- HCl, HBr, HI: These molecules mainly have van der Waals forces (London dispersion forces) acting between them. As molecular mass increases ($\text{Cl} < \text{Br} < \text{I}$), the number of electrons increases and dispersion forces become stronger, so the boiling points rise in the order $\text{HCl} < \text{HBr} < \text{HI}$.
- HF: It deviates greatly from this trend and shows an abnormally high boiling point. This is because fluorine (F) has extremely high electronegativity, so very strong hydrogen bonds form between HF molecules. Because a large amount of energy is required to break these strong intermolecular forces, the boiling point becomes high.

[Examination of the Options]

- (A), (E): HF has the smallest molecular mass and the fewest electrons among the four hydrogen halides. Therefore, dispersion forces should be the weakest.
- (C) HF is a strong acid...: HF is actually a weak acid. Also, acid strength and boiling point are not directly related.
- (D) The H-F bond is weaker...: The strength of intramolecular covalent bonds is not directly related to boiling point (the energy required to break intermolecular forces). Also, the H-F bond is a very strong bond.

[IMAT Perspective]

Learning point: In problems comparing boiling points of molecular substances, the standard approach is to evaluate intermolecular forces in the order: (1) presence or absence of hydrogen bonding, (2) presence or absence of polarity (dipole-dipole interaction), (3) molecular mass (London dispersion forces). The presence of hydrogen bonding has an enormous effect on boiling point.

Question 41

Which of the following reactions is a redox reaction?

- A) $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
 B) $\text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl} + \text{NaNO}_3$
 C) $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$
 D) $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$
 E) $\text{BaCl}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{HCl}$

- Correct Answer: C

[Basis for the Correct Answer]

A redox reaction is a reaction in which oxidation numbers change before and after the reaction. Check the oxidation numbers in each option.

- (C) $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$:
 - Before reaction: H_2 ($\text{H}=0$), Cl_2 ($\text{Cl}=0$)
 - After reaction: HCl ($\text{H}=+1$, $\text{Cl}=-1$)

- Since the oxidation numbers of both hydrogen and chlorine change, this is a redox reaction.

[Examination of the Options] Why are the other options wrong?

- (A) $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$: Acid–base neutralization reaction. There is no change in oxidation numbers.
- (B) $\text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl} + \text{NaNO}_3$: Precipitation reaction (double displacement). There is no change in oxidation numbers.
- (D) $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$: Acid–base reaction (Lewis acid–base). There is no change in oxidation numbers.
- (E) $\text{BaCl}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{HCl}$: Precipitation reaction (double displacement). There is no change in oxidation numbers.

[IMAT Perspective]

Learning point: The most reliable way to determine whether a reaction is a redox reaction is to compare the oxidation numbers of each atom in the reactants and products. Reactions that include elements in their elemental form are almost always redox reactions.

Question 42

Which best describes the pH at the equivalence point of a titration between a weak acid and a strong base?

- A) Less than 7
- B) Equal to 7
- C) Greater than 7
- D) Cannot be determined without concentration
- E) Zero

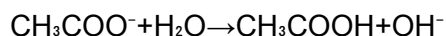
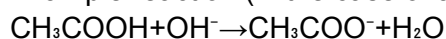
• Correct Answer: C

[Basis for the Correct Answer]

In the titration of a weak acid with a strong base, at the equivalence point the weak acid is completely neutralized, and a salt containing the conjugate base of that weak acid exists in the solution as a product. This conjugate base reacts with water and produces OH^- through basic hydrolysis.

As a result, the solution becomes basic, and the pH is always greater than 7.

Example reaction (in the case of acetic acid and NaOH):



[Examination of the Options] Why are the other options wrong?

- (A) Less than 7: Incorrect. $\text{pH} < 7$ occurs in the case of a strong acid + a weak base.
- (B) Equal to 7: Incorrect. $\text{pH} = 7$ occurs only when a strong acid is neutralized by a strong base.
- (D) Cannot be determined without concentration: Incorrect. The numerical value changes depending on concentration, but the direction ($\text{pH} > 7$) does not change.
- (E) Zero: Incorrect. $\text{pH} = 0$ indicates a very high-concentration acidic solution and does not apply here.

[IMAT Perspective]

Learning point: The pH at the equivalence point of a titration can be predicted from the combination of acid and base strengths.

- Strong acid + strong base \rightarrow pH \approx 7
- Strong acid + weak base \rightarrow pH $<$ 7
- Weak acid + strong base \rightarrow pH $>$ 7

If you keep this relationship in mind, it can also be applied to graph problems and titration curve problems.

Question 43

Which of the following is the correct electron configuration of calcium (Ca)?

- A) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
- B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
- C) $1s^2 2s^2 2p^6 3s^2 3p^6$
- D) $1s^2 2s^2 2p^6 3s^2 3p^4$
- E) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$

- Correct Answer: A

[Basis for the Correct Answer]

Electron configurations follow the Aufbau principle, which fills electrons into orbitals from lower energy levels to higher ones.

1. Atomic number of calcium (Ca): Calcium has atomic number 20, so it has 20 electrons.
2. Filling electrons:
 - 2 electrons in the 1s orbital $\rightarrow 1s^2$
 - 2 electrons in the 2s orbital $\rightarrow 2s^2$
 - 6 electrons in the 2p orbital $\rightarrow 2p^6$
 - 2 electrons in the 3s orbital $\rightarrow 3s^2$
 - 6 electrons in the 3p orbital $\rightarrow 3p^6$
 - Up to here, a total of 18 electrons.
 - Following the order of energy levels, electrons go into the 4s orbital next, not the 3d orbital.
 - 2 electrons in the 4s orbital $\rightarrow 4s^2$
3. Final electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

[IMAT Perspective]

Learning point: It is important to understand the rules for filling electrons into orbitals (Aufbau principle, Pauli exclusion principle, Hund's rule) and to be able to write electron configurations for typical elements up to the 4th period of the periodic table. In particular, do not forget that for K and Ca, electrons fill the 4s orbital before the 3d orbital.

Question 44

In the reaction: $2Ag^+ + Cu \rightarrow Cu^{2+} + 2Ag$

How many grams of silver (Ag, $M=107.9$ g/mol) are formed when 3.00 g of Cu ($M=63.5$ g/mol) reacts completely?

- A) 4.25 g

- B) 5.09 g
- C) 10.2 g
- D) 3.60 g
- E) 6.34 g

• Correct Answer: C

[Basis for the Correct Answer]

1. Calculate the amount of reacted copper (Cu) (moles):
 - Moles of Cu = mass / molar mass = $3.00 \text{ g} / 63.5 \text{ g/mol} \approx 0.04724 \text{ mol}$
 2. Use the coefficient ratio in the reaction equation to find the amount of silver (Ag) produced:
 - The coefficient ratio is Cu : Ag = 1 : 2.
 - Therefore, the moles of Ag produced are twice the moles of Cu that reacted.
 - Moles of Ag = $0.04724 \text{ mol} \times 2 = 0.09448 \text{ mol}$
 3. Calculate the mass of produced silver (Ag):
 - Mass of Ag = moles \times molar mass = $0.09448 \text{ mol} \times 107.9 \text{ g/mol} \approx 10.19 \text{ g}$
- The option closest to 10.19 g is (C) 10.2 g.

[IMAT Perspective]

Learning point: It is important to be able to reliably carry out the basic steps of stoichiometric calculations (mass \rightarrow moles \rightarrow use mole ratio to find moles of the target substance \rightarrow mass).

Question 45

Which statement is true?

- A) C-C bonds are stronger than $\text{C}\equiv\text{C}$
- B) C=C bonds are shorter than $\text{C}\equiv\text{C}$
- C) Bond strength increases with bond order
- D) Triple bonds are weaker than single bonds
- E) Single bonds have highest energy

• Correct Answer: C

[Basis for the Correct Answer]

For carbon-carbon bonds, the bond order, bond strength, and bond length have the following relationships.

- Bond order: single bond (1) < double bond (2) < triple bond (3)
- Bond strength: single bond < double bond < triple bond
- Bond length: single bond > double bond > triple bond

Option (C), "Bond strength increases with bond order," correctly states this relationship.

[Examination of the Options] Why are the other options wrong?

- (A) C-C bonds are stronger than $\text{C}\equiv\text{C}$: Incorrect. A triple bond is stronger than a single bond.
- (B) C=C bonds are shorter than $\text{C}\equiv\text{C}$: Incorrect. A triple bond is shorter than a double bond.
- (D) Triple bonds are weaker than single bonds: Incorrect. Triple bonds are the strongest.

- (E) Single bonds have highest energy: Incorrect. Single bonds have the lowest energy (are weakest).

[IMAT Perspective]

Learning point: The relationships among bond order, bond energy (strength), and bond length are extremely important for understanding chemical bonding. Remember it as an image: "The more bonds there are, the more strongly and more closely the atoms are pulled together."

Question 46

Consider the reversible reaction: $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$, $\Delta H = -57 \text{ kJ/mol}$

Which of the following conclusions are correct?

1. The forward reaction is exothermic.
 2. Decreasing temperature favors formation of NO_2 .
 3. The equilibrium constant increases as temperature decreases.
 4. The catalyst increases the rate of both forward and reverse reactions equally.
- A) 1 and 3 only
 B) 2 and 4 only
 C) 1, 3 and 4 only
 D) 1, 2 and 4 only
 E) 1, 2, 3 and 4
- Correct Answer: C

[Basis for the Correct Answer]

Determine whether each statement is true or false.

1. The forward reaction is exothermic: True. Because the enthalpy change (ΔH) is a negative value (-57 kJ/mol), the forward reaction is exothermic (exothermic).
2. Decreasing temperature favors formation of NO_2 : False. According to Le Chatelier's principle, when temperature decreases, the equilibrium shifts in the direction of the exothermic reaction, that is, toward the forward reaction (toward formation of N_2O_4).
3. The equilibrium constant increases as temperature decreases: True. Because this reaction is exothermic, lowering the temperature shifts equilibrium to the right. Shifting equilibrium toward the products means that the value of the equilibrium constant K becomes larger.
4. The catalyst increases the rate of both forward and reverse reactions equally: True. A catalyst lowers the activation energy equally for the forward and reverse reactions, increasing both reaction rates, but it does not change the equilibrium position itself.

Therefore, the correct statements are 1, 3, and 4.

[IMAT Perspective]

Learning point: Fully understanding Le Chatelier's principle (effects of changes in concentration, pressure, and temperature on equilibrium) is essential. In particular, remember that a change in temperature is the only factor that changes the value of the equilibrium constant K itself (for exothermic reactions, decreasing temperature increases K ; for endothermic reactions, decreasing temperature decreases K).

Question 47

A student adds a piece of metal M into a solution of CuSO_4 and observes that metallic copper forms on the surface of metal M. Later, it is found that the blue color of the Cu^{2+} ion fades gradually.

Which conclusion is most appropriate based on this observation?

- A) Metal M is less reactive than copper.
- B) Copper oxidizes metal M in this reaction.
- C) Metal M is acting as an oxidizing agent.
- D) Metal M is more reactive than copper and is oxidized.
- E) No redox reaction occurs in this process.

• Correct Answer: D

[Basis for the Correct Answer]

Interpret the observed phenomena chemically.

- “Metallic copper forms”: This means that copper ions (Cu^{2+}) in the CuSO_4 aqueous solution gained electrons and became elemental copper (Cu). This is reduction. ($\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$)
- “The blue color of Cu^{2+} fades”: This supports that Cu^{2+} in the solution is decreasing.
- Reaction partner: If Cu^{2+} was reduced, then the reaction partner metal M must have released electrons and become an ion. This is oxidation. ($\text{M} \rightarrow \text{M}^{n+} + n\text{e}^-$)

From the viewpoint of the reactivity series (ionization tendency), since metal M became ions and copper precipitated as a metal, it can be said that metal M has a greater ionization tendency than copper (more reactive, more reactive). A substance that loses electrons and is oxidized acts as a reducing agent.

Therefore, (D) “Metal M is more reactive than copper and is oxidized” is the most appropriate conclusion.

[Examination of the Options] Why are the other options wrong?

- (A) ...less reactive than copper: If reactivity is lower, the reaction does not occur.
- (B) Copper oxidizes metal M...: What oxidizes M is not Cu (the metal) but Cu^{2+} (the ion).
- (C) ...acting as an oxidizing agent: Since M itself is being oxidized, it is a reducing agent.

[IMAT Perspective]

Learning point: It is important to understand the metal reactivity series (ionization tendency) and to be able to judge which metals can precipitate which metal ions from solution.

Section 5: Physics and Mathematics

Question 48

A box contains 5 red balls, 4 blue balls, and 3 green balls. Two balls are drawn at random without replacement. What is the probability that both balls are of the same color?

- A) $19/66$
- B) $5/33$
- C) $2/11$
- D) $1/6$

E) 7/22

- Correct Answer: A

[Basis for the Correct Answer]

“Both are the same color” has three mutually exclusive patterns: “both red” or “both blue” or “both green.” Since these are mutually exclusive, calculate the probability of each pattern and add them.

- Total number of balls: $5 + 4 + 3 = 12$
- Trial: Without replacement (without replacement)
 1. P(both red):
 - $(5/12) \times (4/11) = 20/132$
 2. P(both blue):
 - $(4/12) \times (3/11) = 12/132$
 3. P(both green):
 - $(3/12) \times (2/11) = 6/132$
 4. Total probability:
 - $P(\text{same color}) = P(\text{both red}) + P(\text{both blue}) + P(\text{both green})$
 - $P(\text{same color}) = 20/132 + 12/132 + 6/132 = 38/132$
 5. Reduce the fraction:
 - $38/132 = 19/66$

[IMAT Perspective]

Learning point: In probability problems, it is extremely important to first check whether the trial is “with replacement” or “without replacement.” In without replacement, the numerator and denominator change from the second draw onward.

Question 49

The average of 4 numbers is 58. If one number, 64, is removed, what is the average of the remaining numbers?

- A) 50
- B) 52
- C) 54
- D) 56
- E) 58

- Correct Answer: D

[Basis for the Correct Answer]

1. Find the total of the first four numbers:
 - Total = average \times number of data points
 - Total = $58 \times 4 = 232$
2. Find the total after removing one number:
 - New total = $232 - 64 = 168$
3. Find the average of the remaining numbers:
 - The number of remaining data points is $4 - 1 = 3$.
 - New average = new total / number of remaining data points
 - New average = $168 / 3 = 56$

[IMAT Perspective]

Learning point: Problems that use the relationship between “average” and “total” (total = average \times number) are the basis of data interpretation.

Question 50

In triangle ABC, D and E are points on sides AB and AC respectively such that DE is parallel to BC. If $AD:AB = 2:5$, what is the ratio of the area of triangle ADE to triangle ABC?

- A) 4:25
- B) 2:5
- C) 8:27
- D) 3:9
- E) 1:5

• Correct Answer: A

[Basis for the Correct Answer]

1. Prove the similarity of the triangles:
 - Since $DE \parallel BC$ (DE and BC are parallel), corresponding angles are equal.
 - $\angle ADE = \angle ABC$
 - $\angle AED = \angle ACB$
 - Also, $\angle DAE = \angle BAC$ (common)
 - Therefore, since two pairs of angles are equal, $\triangle ADE \sim \triangle ABC$ (triangles ADE and ABC are similar).
2. Find the area ratio:
 - The area ratio of similar figures is equal to the square of the ratio of corresponding side lengths (similarity ratio).
 - Similarity ratio: $AD:AB = 2:5$
 - Area ratio: $(\text{Area of } \triangle ADE) : (\text{Area of } \triangle ABC) = (AD)^2 : (AB)^2 = 2^2 : 5^2 = 4 : 25$

[IMAT Perspective]

Learning point: The relationships between similarity ratio and area ratio (area ratio = similarity ratio squared), and similarity ratio and volume ratio (volume ratio = similarity ratio cubed), are important formulas in geometry.

Question 51

Given that $\sin(\theta) + \cos(\theta) = 5/4$, where $0 < \theta < \pi/2$, find the exact value of $\sin(2\theta)$.

- A) 5/8
- B) 3/4
- C) 7/8
- D) 9/16
- E) 25/32

• Correct Answer: D

[Basis for the Correct Answer]

This problem is solved by squaring both sides of the given equation and using the double-angle formula of trigonometric functions.

1. Square both sides of the given equation:
 - $(\sin\theta + \cos\theta)^2 = (5/4)^2$
2. Expand the left side:
 - $\sin^2\theta + 2\sin\theta\cos\theta + \cos^2\theta = 25/16$
3. Apply basic trigonometric identities:
 - $\sin^2\theta + \cos^2\theta = 1$
 - $2\sin\theta\cos\theta = \sin(2\theta)$ (double-angle formula)
4. Substitute into the equation and solve:
 - $1 + \sin(2\theta) = 25/16$
 - $\sin(2\theta) = 25/16 - 1 = 9/16$

[IMAT Perspective]

Learning point: When the value of $\sin\theta + \cos\theta$ is given, squaring both sides to find $\sin(2\theta)$ is a typical solution pattern. Be sure to memorize the basic trigonometric identities and the double-angle formulas.

Question 52

Simplify the expression below as a single power of 3:

$$3^{(2x+1)} \cdot 9^{(x-2)} / (27^{(x-3)} \cdot 3^{(x-4)})$$

- A) 3^4
- B) 3^5
- C) 3^{10}
- D) $3^{(x+3)}$
- E) $3^{(2x+1)}$

• Correct Answer: C

[Basis for the Correct Answer]

Convert all terms into exponents with base 3 and calculate using the laws of exponents.

1. Make the base 3:
 - $9 = 3^2$
 - $27 = 3^3$
2. Rewrite the expression:
 - Numerator: $3^{(2x+1)} \cdot (3^2)^{(x-2)} = 3^{(2x+1)} \cdot 3^{(2x-4)}$
 - Denominator: $(3^3)^{(x-3)} \cdot 3^{(x-4)} = 3^{(3x-9)} \cdot 3^{(x-4)}$
3. Calculate the exponents of numerator and denominator:
 - Numerator exponent: $(2x+1) + (2x-4) = 4x-3$
 - Denominator exponent: $(3x-9) + (x-4) = 4x-13$
4. Calculate the exponent of the whole fraction:
 - $3^{(4x-3)} / 3^{(4x-13)} = 3^{((4x-3)-(4x-13))} = 3^{10}$

[IMAT Perspective]

Learning point: In exponent calculations, unifying the base first is the basic strategy. Then, apply the laws of exponents accurately (product \rightarrow add exponents, quotient \rightarrow subtract exponents, power of a power \rightarrow multiply exponents).

Question 53

A sector of a circle has radius 6 cm and central angle 60° . What is the area of the sector?

- A) $6\pi\text{cm}^2$
- B) $9\pi\text{cm}^2$
- C) $12\pi\text{cm}^2$
- D) πcm^2
- E) $36\pi\text{cm}^2$

• Correct Answer: A

[Basis for the Correct Answer]

The formula to find the area of a sector is $\text{Area} = (\text{area of the circle}) \times (\text{central angle} / 360^\circ)$.

- Area of the circle = πr^2
 1. Organize the given values:
 - Radius $r = 6\text{ cm}$
 - Central angle $\theta = 60^\circ$
 2. Substitute into the formula and calculate the area:
 - $\text{Area} = \pi(6)^2 \times 60/360$
 - $\text{Area} = 36\pi \times 1/6$
 - $\text{Area} = 6\pi\text{ cm}^2$

[IMAT Perspective]

Learning point: You must reliably memorize the formulas for the area of a sector and the length of an arc.

Question 54

Solve for all real values of x that satisfy the inequality: $|2x-5| > x+1$

- A) $x < -2$ or $x > 4/3$
- B) $x < -1$ or $x > 6$
- C) $x < 2$ or $x > 4$
- D) $x < 4/3$ or $x > 6$
- E) $x < 4/3$ or $x > 5$

• Correct Answer: D

[Basis for the Correct Answer]

Solve by considering cases depending on whether the inside of the absolute value is nonnegative or negative.

$2x-5=0$ occurs when $x=5/2$.

Case 1: When $x \geq 5/2$

- The absolute value can be removed as is.
- $2x-5 > x+1$
- $x > 6$
- The common range of $x \geq 5/2$ and $x > 6$ is $x > 6$.

Case 2: When $x < 5/2$

- Remove the absolute value with a minus sign.
- $-(2x-5) > x+1 : -2x+5 > x+1$
- $4 > 3x$
- The common range of $x < 5/2$ and $x < 4/3$ is $x < 4/3$.

Combining the results of Case 1 and Case 2, the solution is $x < 4/3$ or $x > 6$.

[IMAT Perspective]

Learning point: For inequalities involving absolute values, case division is fundamental. Do not forget to find the common range between the solution obtained in each case and the condition of that case division.

Question 55

Which statement expresses the second law of thermodynamics?

- A) Energy cannot be created or destroyed.
- B) Heat cannot spontaneously flow from a colder body to a hotter body.
- C) The internal energy of an ideal gas depends only on its temperature.
- D) For adiabatic changes $PV^\gamma = \text{constant}$
- E) The total energy of the universe decreases over time.

• Correct Answer: B

[Basis for the Correct Answer]

The second law of thermodynamics is a law that defines the irreversibility (directionality) of thermal phenomena, and there are several equivalent expressions. One of them is the Clausius statement: "Heat cannot spontaneously flow from a colder body to a hotter body without leaving other changes." Option (B) states this principle accurately. This law can also be expressed as: the entropy of an isolated system changes only in the direction of increase.

[Examination of the Options] Why are the other options wrong?

- (A) Energy cannot be created or destroyed: This is the first law of thermodynamics (law of conservation of energy).
- (C) The internal energy of an ideal gas depends only on its temperature: This is a law about properties of ideal gases (Joule's law).
- (D) For adiabatic changes...: This is Poisson's law for adiabatic changes.
- (E) The total energy of the universe decreases over time: According to the first law of thermodynamics, the total energy of the universe is constant.

[IMAT Perspective]

Learning point: For the laws of thermodynamics (zeroth, first, second), it is important to conceptually understand what each law defines (zeroth → definition of temperature, first → conservation of energy, second → directionality of change).

Question 56

An object is moving at a constant speed of 3 m/s on a rough horizontal surface. A 50 N force is applied to balance the friction. What is the power output of this force?

- A) 15 W
- B) 50 W
- C) 100 W
- D) 150 W
- E) 300 W

• Correct Answer: D

[Basis for the Correct Answer]

One formula for calculating power is $P = Fv$. Here, F is the magnitude of the force and v is the velocity in the direction of the force.

- Because it is moving at a constant speed, the applied force and the frictional force are balanced.
- Because “a 50 N force is applied to balance the friction,” the applied force F is 50 N.
 1. Organize the given values:
 - Force $F = 50 \text{ N}$
 - Velocity $v = 3 \text{ m/s}$
 2. Substitute into the formula and calculate the power P :
 - $P = 50 \text{ N} \times 3 \text{ m/s} = 150 \text{ N} \cdot \text{m/s} = 150 \text{ W (watts)}$

[IMAT Perspective]

Learning point: Memorize both power formulas $P = W/t$ and $P = Fv$, and it is important to be able to use them appropriately depending on the information given in the problem.

Question 57

An object moves in a horizontal circle of radius 4 m at 10 m/s. Its centripetal acceleration is:

- A) 2.5 m s^{-2}
- B) 20 m s^{-2}
- C) 25 m s^{-2}
- D) 40 m s^{-2}
- E) 50 m s^{-2}

- Correct Answer: C

[Basis for the Correct Answer]

The formula for centripetal acceleration (centripetal acceleration) in uniform circular motion is $a = v^2/r$.

1. Organize the given values:
 - Speed $v = 10 \text{ m/s}$
 - Radius $r = 4 \text{ m}$
2. Substitute into the formula and calculate:
 - $a = 10^2/4 = 25 \text{ m/s}^2$

[IMAT Perspective]

Learning point: Be sure to memorize the basic formulas for uniform circular motion (centripetal acceleration $a = v^2/r = r\omega^2$, centripetal force $F_c = mv^2/r = mr\omega^2$).

Question 58

A 2.0 kg object initially at rest is acted upon by a force that delivers an impulse of 10 N·s. What is its final velocity?

- A) 2.0 m/s
- B) 3.5 m/s
- C) 5.0 m/s
- D) 10.0 m/s
- E) 20.0 m/s

- Correct Answer: C

[Basis for the Correct Answer]

Use the relationship that impulse is equal to the change in momentum.

- Impulse = change in momentum
- $I = \Delta p = m v_{\text{final}} - m v_{\text{initial}}$
 1. Organize the given values:
 - Impulse $I = 10 \text{ N}\cdot\text{s}$
 - Mass $m = 2.0 \text{ kg}$
 - Initial velocity $v_{\text{initial}} = 0 \text{ m/s}$
 - Final velocity $v_{\text{final}} = \text{unknown}$
 2. Substitute into the formula and calculate the final velocity:
 - $10 = (2.0 \times v_{\text{final}}) - (2.0 \times 0)$
 - $10 = 2.0 \times v_{\text{final}}$
 - $v_{\text{final}} = 5.0 \text{ m/s}$

[IMAT Perspective]

Learning point: The relationship between impulse and momentum is an important concept in mechanics. Understand that impulse equals the change in momentum and be able to apply the formula.

Question 59

A car of mass 1,000 kg is traveling at 20 m/s when brakes are applied. If the car stops in 4.0 s, what is the average power dissipated?

- A) 25,000 W
- B) 40,000 W
- C) 50,000 W
- D) 75,000 W
- E) 100,000 W

• Correct Answer: C

[Basis for the Correct Answer]

Average power is found by dividing the work done (or energy lost) by the time taken.

- Average power $P = (\text{work } W) / (\text{time } t)$
 1. Calculate the energy lost due to braking:
 - The work done by braking equals the change in the car's kinetic energy (work–energy theorem).
 - Initial kinetic energy $KE_{\text{initial}} = (1/2) m v^2 = (1/2) \times 1000 \times (20)^2 = 500 \times 400 = 200,000 \text{ J}$
 - Final kinetic energy $KE_{\text{final}} = 0 \text{ J}$ (stops)
 - Lost energy (work done by brakes) $W = 200,000 \text{ J}$
 2. Calculate the average power:
 - Time $t = 4.0 \text{ s}$
 - $P = 200,000 \text{ J} \div 4.0 \text{ s} = 50,000 \text{ W}$

[IMAT Perspective]

Learning point: This problem combines two important concepts: the work–energy theorem (work = change in kinetic energy) and the definition of power (power = work/time).

Question 60

Two parallel plate capacitors, $C_1=4\ \mu\text{F}$ and $C_2=6\ \mu\text{F}$, are connected in series to a 12 V battery. Consider the following statements: Which statement is false?

- A) The equivalent capacitance is less than either C_1 or C_2 .
- B) Both capacitors store the same amount of charge.
- C) The voltage across C_1 is greater than that across C_2 .
- D) The total energy stored in the system is given by $(1/2) \times C_{\text{eq}} \times V^2$ where C is the equivalent capacitance.
- E) The capacitor with the larger capacitance has a larger voltage across it.

• Correct Answer: E

[Basis for the Correct Answer]

This problem asks you to choose the incorrect statement among those about capacitors connected in series.

Determine whether each statement is true or false.

- (A) The equivalent capacitance is less than either C_1 or C_2 : True. The equivalent capacitance for a series connection C_{eq} is calculated by $1/C_{\text{eq}} = 1/C_1 + 1/C_2$, and it is always smaller than the individual capacitances.
- (B) Both capacitors store the same amount of charge: True. In a series connection, the charge Q stored on each capacitor is equal ($Q_1=Q_2=Q_{\text{total}}$).
- (C) The voltage across C_1 is greater than that across C_2 : True. From $Q = CV$, voltage $V = Q/C$. Since charge Q is the same, the capacitor with smaller capacitance C has a larger voltage V across it. Because $C_1 < C_2$, $V_1 > V_2$.
- (D) The total energy stored...: True. This is the formula for the energy stored in capacitors.
- (E) The capacitor with the larger capacitance has a larger voltage across it: False. As in (C), voltage is inversely proportional to capacitance. Therefore, the capacitor with the larger capacitance (C_2) has the smaller voltage across it.

[IMAT Perspective]

Learning point: For series and parallel capacitor connections, it is essential to accurately understand and compare the equivalent capacitance, the voltage across each capacitor, and the relationship of stored charge.