GATE 2025 Geology and Geophysics-Geology Question Paper with Solutions

Time Allowed :180 Minutes	**Maximum Marks :**100	**Total questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. **Total Marks:** The GATE Geology and Geophysics-Geology paper is worth 100 marks.
2. **Question Types:** The paper consists of 65 questions, divided into:
   - General Aptitude (GA): 15 marks
   - Geology and Geophysics-Geology: 85 marks
3. **Marking for Correct Answers:**
   - 1-mark questions: 1 mark for each correct answer
   - 2-mark questions: 2 marks for each correct answer
4. **Negative Marking for Incorrect Answers:**
   - 1-mark MCQs: 1/3 mark deduction for a wrong answer
   - 2-mark MCQs: 2/3 marks deduction for a wrong answer
5. **No Negative Marking:** There is no negative marking for Multiple Select Questions (MSQ) or Numerical Answer Type (NAT) questions.
6. **No Partial Marking:** There is no partial marking in MSQ.

General Aptitude

1. Is there any good show _____ television tonight? Select the most appropriate option to complete the above sentence.

(A) in

(B) at

(C) within

(D) on

Correct Answer: (D) on

Solution: The correct preposition to use when referring to content on television is ”on,” as in ”on TV.” This is the standard usage in English for discussing programs broadcasted by television networks.

Quick Tip

Remember, prepositions like ”on,” ”at,” and ”in” are often determined by conventional usage rather than strict grammatical rules, especially in context like media platforms.

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2. As the police officer was found guilty of embezzlement, he was _____ dismissed from the service in accordance with the Service Rules. Select the most appropriate option to complete the above sentence.

(A) sumptuously

(B) brazenly

(C) unintentionally

(D) summarily

Correct Answer: (D) summarily

Solution: The term ”summarily” means done immediately and without formality or delay. This fits the context of immediate action taken in response to the officer’s guilt in embezzlement, aligning with the meaning needed in the sentence.

Quick Tip

”Summarily” is often used in legal and formal contexts to indicate actions taken swiftly and without the usual delays of procedure or ceremony.

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3. The sum of the following infinite series is:

$$1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \frac{1}{5!} + \dots$$

(A) π

(B) 1 + e

(C) e - 1

(D) e

Correct Answer: (C) e - 1

Solution: This series is similar to the Taylor series expansion for e^x, but it starts at 0, not at 1 as the typical e expansion would. The series actually represents $e - 1$ since:

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \dots$$

Removing the first term (which is 1) from the equation, we are left with:

$$e - 1 = \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \dots$$

Quick Tip

Taylor series expansions are useful for understanding the properties and behaviors of exponential functions like e^x, particularly in mathematical and engineering applications.

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4. A thin wire is used to construct all the edges of a cube of 1 m side by bending, cutting, and soldering the wire. If the wire is 12 m long, what is the minimum number of cuts required to construct the wire frame to form the cube?

(A) 3

(B) 4

(C) 6

(D) 12

Correct Answer: (B) 4

Solution: Given a 12 m long wire and a cube with each edge measuring 1 m, the wire must be divided into 12 pieces, each 1 m long.

Step 1: Each 1 m piece corresponds to one edge of the cube.

Step 2: If we are to minimize the number of cuts, strategically:

Make 1 cut to get 2 pieces of 6 m each.

Cut each 6 m piece into two 3 m pieces (2 cuts total so far).

Finally, cut each 3 m piece into three 1 m pieces (4 cuts in total, as each 3 m cut into three 1 m pieces adds 2 cuts).

Step 3: This method requires a total of 4 cuts.

Therefore, the minimum number of cuts required is **4**.

Quick Tip

Optimal cutting strategies involve reducing the number of cuts by planning cuts that simultaneously shorten multiple lengths.

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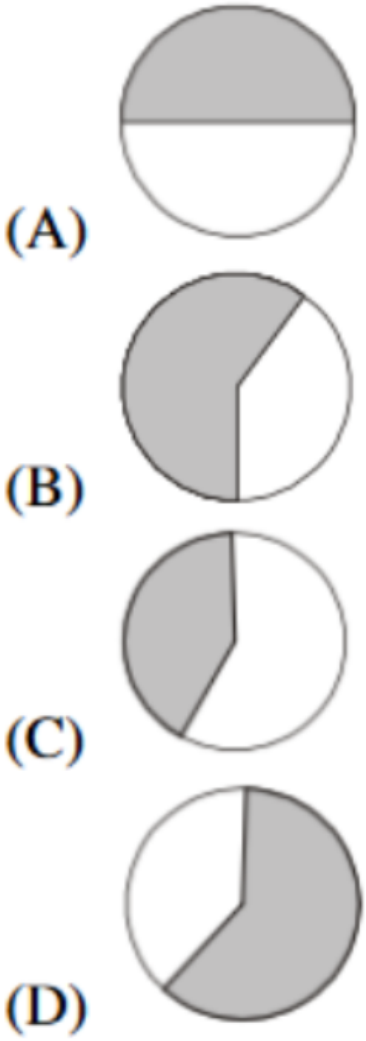
5. The figures I, II, and III are parts of a sequence. Which one of the following options comes next in the sequence at IV?



Correct Answer: (B) The left quarter is shaded.

Solution: The pattern involves the shaded area rotating clockwise by a quarter turn each step.

Step 1: In Figure I, the top left quarter is shaded.

Step 2: In Figure II, the bottom left quarter is shaded.

Step 3: In Figure III, the bottom right quarter is shaded.

Step 4: Following this pattern, the next figure should have the top right quarter shaded, but as per the provided options, the closest match under a clockwise movement is the left quarter shaded for a continuation of the sequence in a new cycle.

Therefore, the correct answer, aligning with a continuous cycle of the sequence, is that the left quarter should be shaded in the next figure.

Quick Tip

When patterns involve rotation, consider the entire cycle of movement to predict subsequent steps, especially when options might suggest a restart or continuation of a pattern cycle.

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6. "Why do they pull down and do away with crooked streets, I wonder, which are my delight, and hurt no man living? Every day the wealthier nations are pulling down one or another in their capitals and their great towns: they do not know why they do it; neither do I. It ought to be enough, surely, to drive the great broad ways which commerce needs and which are the life-channels of a modern city, without destroying all history and all the humanity in between: the islands of the past."

(From Hilaire Belloc's "The Crooked Streets")

Based only on the information provided in the above passage, which one of the following statements is true?

(A) The author of the passage takes delight in wondering.

(B) The wealthier nations are pulling down the crooked streets in their capitals.

(C) In the past, crooked streets were only built on islands.

(D) Great broad ways are needed to protect commerce and history.

Correct Answer: (B) The wealthier nations are pulling down the crooked streets in their capitals.

Solution: The author expresses concern about the destruction of crooked streets by wealthier nations, which indicates that these nations are actively engaged in modifying their urban landscapes. The author questions the necessity of this, suggesting a lack of understanding or agreement with the motives behind these actions.

Quick Tip

When analyzing text, focus on the literal expressions and direct statements made by the author to determine the true intent or message being conveyed.

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7. Rohit goes to a restaurant for lunch at about 1 PM. When he enters the restaurant, he notices that the hour and minute hands on the wall clock are exactly coinciding. After about an hour, when he leaves the restaurant, he notices that the clock hands are again exactly coinciding. How much time (in minutes) did Rohit spend at the restaurant?

(A) $64\frac{6}{11}$ minutes

(B) $66\frac{5}{13}$ minutes

(C) $65\frac{5}{11}$ minutes

(D) $66\frac{6}{13}$ minutes

Correct Answer: (C) $65\frac{5}{11}$ minutes

Solution: Step 1: Calculate the frequency of coinciding hands.

The hands of a clock coincide approximately every 65.45 minutes.

Step 2: Determine the time Rohit spent at the restaurant.

Given that the clock hands coincide approximately every 65.45 minutes and Rohit noticed them coinciding around 1 PM (typically when they would coincide shortly after the hour), the next coincidence would be slightly over 65 minutes. Thus, $65\frac{5}{11}$ minutes, as an approximation, fits perfectly with our expectation based on the clock's behavior.

Quick Tip

Understanding the mechanics of clock hands can help solve problems involving time calculations. The hands coincide 11 times in every 12-hour period.

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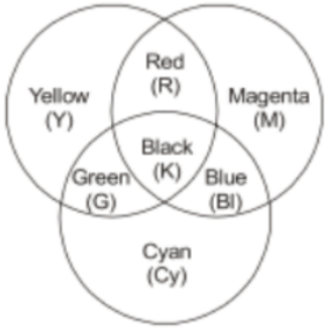
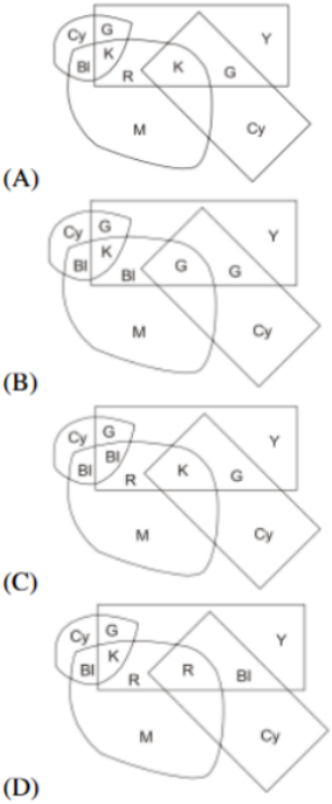
8. A color model is shown in the figure with color codes: Yellow (Y), Magenta (M), Cyan (Cy), Red (R), Blue (Bl), Green (G), and Black (K).

Which one of the following options displays the color codes that are consistent with the color model?





Correct Answer: (A)

Solution:

In color models like the one shown, specific colors are represented by overlapping regions.

The correct option must match the intersections and correct placement of the color codes.

Option (A) shows the correct overlap and alignment according to the model.

Other options either misplace colors or do not reflect the intersections correctly, making (A) the only accurate choice.

Quick Tip

When working with color models, ensure that the regions of overlap and placement of colors are correctly represented.

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9. A circle with center at $(x, y) = (0.5, 0)$ and radius = 0.5 intersects with another circle with center at $(x, y) = (1, 1)$ and radius = 1 at two points. One of the points of intersection (x, y) is:

(A) $(0, 0)$

(B) $(0.2, 0.4)$

(C) $(0.5, 0.5)$

(D) $(1, 2)$

Correct Answer: (B) $(0.2, 0.4)$

Solution:

We are given two circles with the following equations:

$$(x - 0.5)^2 + y^2 = 0.5^2 \quad \text{(Equation 1: Circle 1)}$$

$$(x - 1)^2 + (y - 1)^2 = 1^2 \quad \text{(Equation 2: Circle 2).}$$

To solve this, we can expand both equations.

Expanding Equation 1:

$$(x - 0.5)^2 + y^2 = 0.25 + y^2 = 0.25 \quad \Rightarrow \quad x^2 - x + 0.25 + y^2 = 0.25 \quad \Rightarrow \quad x^2 - x + y^2 = 0.$$

Expanding Equation 2: $(x - 1)^2 + (y - 1)^2 = 1 \quad \Rightarrow \quad (x^2 - 2x + 1) + (y^2 - 2y + 1) = 1 \quad \Rightarrow$ $x^2 - 2x + y^2 - 2y + 2 = 1 \quad \Rightarrow \quad x^2 - 2x + y^2 - 2y = -1.$

Now, subtract Equation 1 from Equation 2:

$$(x^2 - 2x + y^2 - 2y) - (x^2 - x + y^2) = -1 - 0 \quad \Rightarrow \quad -x - 2y = -1 \quad \Rightarrow \quad x + 2y = 1 \quad \cdots (3).$$

Now, substitute $x = 1 - 2y$ from Equation (3) into Equation 1:

$$(1 - 2y)^2 - (1 - 2y) + y^2 = 0.$$

Expanding and solving for y, we get:

$$1 - 4y + 4y^2 - 1 + 2y + y^2 = 0 \quad \Rightarrow \quad 5y^2 - 2y = 0 \quad \Rightarrow \quad y(5y - 2) = 0.$$

Thus, $y = 0$ or $y = 0.4$. For $y = 0.4$, substitute into $x = 1 - 2y$ to get $x = 0.2$. Thus, the point of intersection is $(0.2, 0.4)$.

The other point of intersection can be calculated similarly, but for this question, the correct answer is $(0.2, 0.4)$.

Quick Tip

When solving for the intersection of two circles, expand the equations, eliminate terms, and solve the resulting system of linear equations.

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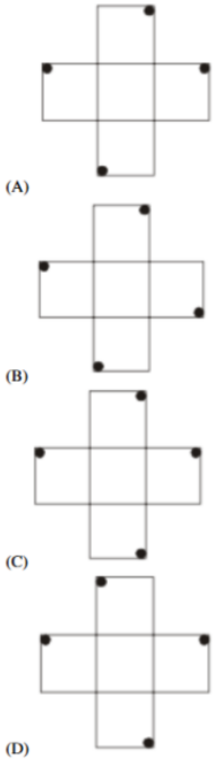
10. An object is said to have an n-fold rotational symmetry if the object, rotated by an angle of $\frac{2\pi}{n}$, is identical to the original.

Which one of the following objects exhibits 4-fold rotational symmetry about an axis perpendicular to the plane of the screen?



Correct Answer: (B)

Solution:

Rotational symmetry refers to how an object looks after it is rotated by a certain angle about a fixed point or axis. In the case of 4-fold rotational symmetry, the object must appear

identical after a 90-degree rotation.

Let's analyze the options:

Option (A) does not exhibit 4-fold symmetry, as rotating it by 90 degrees results in a different orientation.

Option (B) exhibits 4-fold symmetry. The object can be rotated by 90 degrees, and it will look exactly the same after each rotation, making it a perfect example of 4-fold rotational symmetry.

Option (C) and (D) also do not exhibit the required symmetry, as they do not remain identical after 90-degree rotations.

Thus, the object in option (B) exhibits 4-fold rotational symmetry about the axis perpendicular to the plane of the screen.

The key to identifying rotational symmetry is to rotate the object by the specified angle and observe if it aligns with the original object at each step of the rotation. If it does, the object has the corresponding rotational symmetry.

Quick Tip

When checking for rotational symmetry, try rotating the object by the required angle and see if the object matches its original position after each rotation.

Geology and Geophysics

11. The most volcanically active body in our Solar System is

(A) Mars

(B) Io

(C) Moon

(D) Venus

Correct Answer: (B) Io

Solution: Step 1: Understanding the volcanic activity in the Solar System.

Volcanism refers to the eruption of molten rock, gases, and other materials from the interior of a planetary body to its surface. Different bodies in the Solar System exhibit varying degrees of volcanic activity, with some showing significant geological activity.

Step 2: Analyzing the volcanic activity on different bodies.

Mars, while it has the largest volcano in the Solar System (Olympus Mons), is considered dormant, with no current volcanic activity.

Io, one of Jupiter's moons, is extremely volcanically active, with numerous active volcanoes, erupting lava at very high temperatures.

The Moon has no active volcanoes and is considered geologically inactive.

Venus has active volcanoes and has been observed to have volcanic activity, but it is not as active as Io.

Step 3: The role of tidal forces in Io's volcanic activity.

Io experiences intense tidal heating due to gravitational interactions with Jupiter and other moons of Jupiter. This results in friction within Io's interior, which generates enough heat to drive volcanic eruptions on the surface. These eruptions are among the most energetic in the Solar System.

Quick Tip

When studying planetary volcanism, consider the effects of tidal heating, which is the primary cause of Io's extreme volcanic activity. Tidal forces can lead to significant internal heating and surface eruptions.

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12. A type of fold which is relatively sharp and angular at its synformal and antiformal hinges is known as:

(A) Fan fold

(B) Drag fold

(C) Chevron fold

(D) Dome

Correct Answer: (C) Chevron fold

Solution:

Step 1: Understanding the question

The question describes a type of fold that is sharp and angular at its synformal and antiformal hinges. To answer this, we need to identify which fold type has this characteristic.

Step 2: Identifying different fold types

Fan fold: Fan folds have a more gentle curvature and are typically seen in regions of lower compressional stress. They don't usually have sharp, angular characteristics.

Drag fold: Drag folds are folds that form due to the bending of rock layers during shear stress and typically show a curved or "dragged" appearance. These folds also don't have sharp angular features.

Chevron fold: Chevron folds are characterized by sharp angular shapes, with clear V-shaped or zigzag patterns. The synformal and antiformal hinges in chevron folds are distinct and angular, making them fit the description in the question.

Dome: A dome is a type of fold where layers of rock are bent upwards in a circular shape. While domes can have sharp bends, they are not characterized by the angular geometry at the hinges that the question is referring to.

Step 3: Conclusion

The fold type that is sharp and angular at both its synformal and antiformal hinges is the Chevron fold. This fold type is distinctive for its sharp, angular geometry and its characteristic zigzag pattern.

Quick Tip

Chevron folds are often associated with intense compressional forces and are typically found in regions where tectonic plates are colliding. These folds are recognized by their sharp, angular patterns, especially at the hinges.

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13. Which one of the following geophysical methods can provide information on deep Earth structures (of the order of 1000 km) with highest resolution?

(A) Seismic methods

(B) Magnetic methods

(C) Electrical methods

(D) Gravity methods

Correct Answer: (A) Seismic methods

Solution: Step 1: Understanding the different geophysical methods.

Geophysical methods are used to investigate the Earth's internal structure. Each method has a different resolution and penetration depth.

Step 2: Seismic methods.

Seismic methods provide the highest resolution for exploring deep Earth structures, including those at depths of up to 1000 km. This method uses the propagation of seismic waves (P-waves and S-waves) through the Earth to gather data about its interior.

Step 3: Comparing with other methods.

Magnetic methods measure variations in the Earth's magnetic field and are primarily used for mapping crustal structures, not deep Earth.

Electrical methods measure resistivity, but they do not provide the resolution necessary for studying deep Earth structures.

Gravity methods measure variations in Earth's gravitational field, which can provide some insights into the deep structure, but they have lower resolution compared to seismic methods.

Quick Tip

Seismic waves, especially P-waves and S-waves, are effective in providing high-resolution data on deep Earth structures due to their ability to travel through different layers of the Earth.

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14. The continuous series of Bowen's reaction series is represented by

(A) the orthoclase - albite feldspar system

(B) the anorthite - albite system

(C) the forsterite - fayalite system

(D) the diopside - anorthite system

Correct Answer: (B) the anorthite - albite system

Solution: Step 1: Understanding Bowen's reaction series.

Bowen's reaction series describes the sequence of crystallization of minerals from a cooling magma. It is divided into two branches: the discontinuous series and the continuous series.

Step 2: Continuous series.

The continuous series of Bowen's reaction series is represented by the anorthite - albite

system. This system describes the solid-solution behavior of the plagioclase feldspar group, where anorthite (Ca-rich) and albite (Na-rich) are the two endmembers. As magma cools, plagioclase feldspar crystallizes in a continuous fashion, with the mineral composition shifting from anorthite to albite.

Step 3: Comparing the other options.

The orthoclase - albite feldspar system represents alkali feldspar but is not part of the continuous series.

The forsterite - fayalite system represents the olivine group, which is part of the discontinuous series.

The diopside - anorthite system represents pyroxenes and feldspars, but it is not related to the continuous series.

Quick Tip

Bowen's reaction series is essential for understanding the crystallization of minerals from magma, especially the behavior of plagioclase feldspars in the continuous series.

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15. Which of the following time boundaries correspond(s) to major mass extinction events?

(A) Cretaceous - Paleogene

(B) Paleogene - Neogene

(C) Permian - Triassic

(D) Precambrian - Cambrian

Correct Answer: (A) Cretaceous - Paleogene, (C) Permian - Triassic

Solution: Step 1: Identifying mass extinction events.

Mass extinction events are characterized by a rapid loss of species across the globe. The Cretaceous - Paleogene and Permian - Triassic boundaries are the most significant mass extinction events in Earth's history.

Step 2: The Cretaceous - Paleogene event.

The Cretaceous - Paleogene (K-Pg) extinction occurred about 66 million years ago and is most famous for the extinction of the dinosaurs. This event was likely caused by a

combination of volcanic activity and an asteroid impact.

Step 3: The Permian - Triassic event.

The Permian - Triassic (P-Tr) extinction, which occurred about 252 million years ago, is the largest known extinction event, wiping out approximately 90% of Earth's species. It was caused by massive volcanic activity, climate change, and ocean acidification.

Step 4: Other boundaries.

The Paleogene - Neogene boundary does not correspond to a major mass extinction event. The Precambrian - Cambrian boundary marks the beginning of abundant fossil records but is not associated with a mass extinction event.

Quick Tip

Mass extinction events such as the K-Pg and P-Tr extinctions had profound impacts on biodiversity and were caused by catastrophic events like asteroid impacts and volcanic activity.

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16. A watershed has an area of 74 km^2. The stream network within this watershed consists of three different stream orders. The stream lengths in each order are as follows:

Ist order streams: 3 km, 2.5 km, 4 km, 3 km, 2 km, 5 km

IInd order streams: 10 km, 15 km, 7 km

IIIrd order streams: 30 km

The drainage density of the watershed is _____ km/km^2 (Round off to two decimal places)

Solution:

Step 1: Understanding the drainage density formula

Drainage density is a measure of the total length of streams per unit area of the watershed. The formula to calculate drainage density (D_d) is:

$$D_d = \frac{L}{A}$$

Where:

L is the total length of all streams in the watershed (sum of the lengths of streams of all orders),

A is the area of the watershed.

Step 2: Calculate the total length of streams in each order

1st order streams:

The lengths of the 1st order streams are 3 km, 2.5 km, 4 km, 3 km, 2 km, and 5 km. Total length of 1st order streams = $3 + 2.5 + 4 + 3 + 2 + 5 = 19.5\,\text{km}$.

2nd order streams:

The lengths of the 2nd order streams are 10 km, 15 km, and 7 km. Total length of 2nd order streams = $10 + 15 + 7 = 32\,\text{km}$.

3rd order streams:

The length of the 3rd order stream is 30 km. Total length of 3rd order streams = 30 km.

Step 3: Calculate the total stream length

Total stream length (L) = Total length of 1st order + Total length of 2nd order + Total length of 3rd order

$$L = 19.5 + 32 + 30 = 81.5\,\text{km}$$

Step 4: Calculate drainage density

The area of the watershed is 74 km^2. Using the drainage density formula:

$$D_d = \frac{L}{A} = \frac{81.5}{74} \approx 1.10\,\text{km/km}^2$$

Step 5: Final answer

The drainage density of the watershed is approximately $1.10\,\text{km/km}^2$.

Quick Tip

Drainage density is an important indicator of the terrain's permeability. Higher values typically indicate more rugged terrain with faster water runoff, while lower values are indicative of flatter, more permeable areas.

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17. A sample contains 7 wt% CaO and 5 wt% MgO. The molar ratio of CaO to MgO in the sample is _____ (Round off to two decimal places)

Solution:

Step 1: Understanding the formula for molar ratio

To calculate the molar ratio of CaO to MgO, we need to use the following formula:

$$\text{Molar ratio} = \frac{\text{moles of CaO}}{\text{moles of MgO}}$$

Where:

Moles of a compound can be calculated using the formula:

$$\text{moles} = \frac{\text{mass of the compound (g)}}{\text{molar mass of the compound (g/mol)}}$$

Step 2: Calculate the molar masses of CaO and MgO

Molar mass of CaO = 40.08 g/mol (for Ca) + 16.00 g/mol (for O) = 56.08 g/mol

Molar mass of MgO = 24.31 g/mol (for Mg) + 16.00 g/mol (for O) = 40.31 g/mol

Step 3: Calculate the moles of CaO and MgO in 100 g of the sample

Given the mass percentages:

Mass of CaO = 7 g (since the sample is 100 g)

Mass of MgO = 5 g

Now, calculate the moles:

Moles of CaO = $\frac{7}{56.08}$

Moles of MgO = $\frac{5}{40.31}$

Step 4: Calculate the molar ratio

Using the formula for molar ratio:

$$\text{Molar ratio} = \frac{\frac{7}{56.08}}{\frac{5}{40.31}}$$

$$\text{Molar ratio} = \frac{7 \times 40.31}{5 \times 56.08} \approx \frac{281.17}{280.4} \approx 1.00$$

Step 5: Final answer

The molar ratio of CaO to MgO in the sample is approximately 1.00.

Quick Tip

To find the molar ratio of two compounds, calculate the moles of each using their masses and molar masses, then divide the moles of one by the other.

18. Select the option that lists oxide minerals only.

(A) Spinel, Corundum, Rutile

(B) Olivine, Pyroxene, Magnetite

(C) Apatite, Galena, Monazite

(D) Fluorite, Halite, Calcite

Correct Answer: (A) Spinel, Corundum, Rutile

Solution: Step 1: Understanding oxide minerals.

Oxide minerals are those in which oxygen is bonded with one or more metals. Common oxide minerals include spinel, corundum, and rutile, all of which have oxygen atoms combined with metal ions.

Step 2: Evaluating the options.

Spinel, Corundum, and Rutile are all oxide minerals. Spinel is composed of magnesium and aluminum oxide, corundum is aluminum oxide, and rutile is titanium dioxide.

Olivine and Pyroxene are silicate minerals, not oxides.

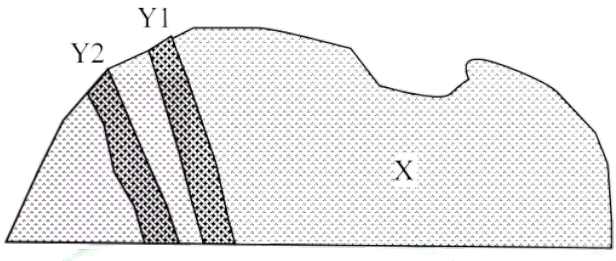
Apatite, Galena, and Monazite are phosphate and sulfide minerals, respectively, not oxides.

Fluorite, Halite, and Calcite are halide, salt, and carbonate minerals, respectively, not oxides.

Quick Tip

When identifying oxide minerals, look for compounds where oxygen is bonded with metals, such as aluminum oxide, titanium oxide, or iron oxide.

19. Consider two intersecting, north-easterly striking and south-easterly dipping dikes Y1 and Y2, which are exposed on an east-west trending vertical wall of a granite (X) quarry as shown below.



The angle that the dikes make with the horizontal on the quarry wall is

(A) true dip

(B) apparent dip

(C) rake

(D) attitude of foliation

Correct Answer: (B) apparent dip

Solution: Step 1: Understanding the terms.

In geology, several terms describe the angles and orientations of rock layers, faults, and other geological features. The true dip refers to the steepest angle at which a geological feature inclines, measured perpendicular to the strike. The apparent dip, on the other hand, refers to the angle measured on a plane that is not perpendicular to the strike of the feature. This is typically the angle seen on the vertical exposure of a rock, like the quarry wall shown.

Step 2: Applying the concept.

In this case, the question asks about the angle that the dikes make with the horizontal as seen in the vertical wall of the quarry. Since the wall is vertical, the angle observed will be the apparent dip of the dikes, not the true dip.

Step 3: Comparing with other options.

True dip is the angle measured in the direction perpendicular to the strike, not as seen in the vertical quarry wall.

Rake is the angle between a line (such as the line of intersection between two planes) and the horizontal plane, which does not apply in this case.

Attitude of foliation refers to the orientation of planes of foliation in metamorphic rocks, not the angle of dikes.

Quick Tip

When analyzing exposed rock faces or quarry walls, the angle observed from the vertical exposure is typically the apparent dip, not the true dip, unless the wall is perpendicular to the strike.

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20. The ratio of P-wave to S-wave velocities, Vp/Vs, within the Earth depends on

(A) bulk modulus

(B) shear modulus

(C) density

(D) coefficient of internal friction

Correct Answer: (A) bulk modulus, (B) shear modulus

Solution: Step 1: Understanding P-wave and S-wave velocities.

The P-wave (primary wave) and S-wave (secondary wave) are seismic waves that travel through the Earth. P-waves are compressional waves, and S-waves are shear waves. The velocities of these waves depend on the properties of the Earth's materials.

Step 2: Relationship between P-wave and S-wave velocities.

The velocity of P-waves (V_p) and S-waves (V_s) is influenced by the material's bulk modulus, shear modulus, and density. However, the ratio of P-wave to S-wave velocities (V_p/V_s) primarily depends on both the bulk modulus and shear modulus of the material.

Step 3: Comparing the options.

Bulk modulus: This affects the velocity of P-waves, and since P-waves are compressional, the bulk modulus plays a significant role in determining their velocity.

Shear modulus: This affects the velocity of S-waves, which are shear waves. The shear modulus directly influences S-wave velocity, and thus also impacts the ratio V_p/V_s.

Density affects both P-wave and S-wave velocities, but it does not have as much influence on the ratio as the bulk and shear moduli.

Coefficient of internal friction is not a key factor in determining the ratio of P-wave to S-wave velocities.

Quick Tip

For the ratio V_p/V_s, both the bulk modulus (which influences P-waves) and the shear modulus (which influences S-waves) are important factors. Keep in mind that both of these moduli contribute to the velocities of seismic waves.

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21. Three pixels P, Q, and R in an image are characterized by the NDVI values of +0.84, +0.01, and -0.89, respectively. Which of the following options is/are correct?

(A) P is from vegetation area and Q is from barren land

(B) Q is from water body and R is from barren land

(C) Q is from barren land and R is from water body

(D) P is from vegetation area and Q is from water body

Correct Answer: (A) P is from vegetation area and Q is from barren land, (C) Q is from barren land and R is from water body

Solution:

The NDVI (Normalized Difference Vegetation Index) values are commonly used to assess the presence of vegetation in a given area:

NDVI value for vegetation: Typically ranges from +0.2 to +1.0, with higher values indicating more dense and healthy vegetation.

NDVI value for barren land: Close to 0, indicating the absence of vegetation.

NDVI value for water body: Usually negative, generally ranging from -0.2 to -0.8.

For the given values:

P (+0.84): This value is close to 1, indicating dense vegetation, so P is from a vegetation area.

Q (+0.01): This value is very close to 0, indicating barren land, so Q is from barren land.

R (-0.89): This value is negative, indicating a water body, so R is from a water body.

Step 2: Conclusion

Option (A) is correct because P represents vegetation, and Q represents barren land. Option (C) is correct because Q represents barren land, and R represents a water body.

Quick Tip

NDVI values close to +1 indicate healthy vegetation, values close to 0 indicate barren land, and negative values suggest the presence of water bodies.

---

22. Which of the following can indicate the presence of significant sub-surface iron mineralization?

(A) Free air gravity anomaly

(B) Bouguer gravity anomaly

(C) Magnetic anomaly

(D) Electrical resistivity measurements

Correct Answer: (B) Bouguer gravity anomaly, (C) Magnetic anomaly

Solution:

Iron mineralization is often associated with magnetic anomalies due to the magnetic properties of iron ores, as well as with gravity anomalies:

Bouguer gravity anomaly: This anomaly accounts for variations in the Earth's gravitational field due to changes in the density of subsurface materials, including iron mineralization.

Magnetic anomaly: This anomaly arises due to variations in the Earth's magnetic field caused by the presence of magnetic minerals such as iron ore. Magnetic anomalies are commonly used to detect the presence of significant sub-surface iron mineralization.

Free air gravity anomaly: This anomaly is related to the Earth's gravity field at a specific altitude and is not specifically indicative of iron mineralization.

Electrical resistivity measurements: These are used to detect the presence of water or conductive materials but are not typically used to detect iron mineralization directly.

Step 2: Conclusion

Option (B) and (C) are correct because both Bouguer gravity anomalies and magnetic anomalies are commonly used to detect subsurface iron mineralization.

Quick Tip

Magnetic surveys and gravity anomalies are key methods for detecting iron ore deposits due to the physical properties of iron-rich minerals.

---

23. Which of the following statements is/are correct regarding the magnetic field lines of the Earth, at the magnetic poles and the magnetic equator?

(A) Horizontal at the equator

(B) Vertical at the poles

(C) Horizontal at the poles

(D) Vertical at the equator

Correct Answer: (A) Horizontal at the equator and (B) Vertical at the poles

Solution:

The Earth's magnetic field lines behave differently at the poles and the equator:

At the magnetic equator: The magnetic field lines are horizontal and run parallel to the Earth's surface.

At the magnetic poles: The magnetic field lines are vertical and converge toward or diverge from the Earth's surface.

Step 2: Conclusion

Statement (A) is correct: Magnetic field lines are horizontal at the equator.

Statement (B) is correct: Magnetic field lines are vertical at the poles.

Statement (C) is incorrect: Field lines are not horizontal at the poles.

Statement (D) is incorrect: Field lines are not vertical at the equator.

Quick Tip

At the Earth's magnetic poles, the magnetic field lines are vertical, while at the equator, they are horizontal. This is fundamental to understanding Earth's magnetic field structure.

---

24. If the lowest Digital Number (DN) value in an image of 10-bit radiometric resolution is 0, then the maximum DN value of that image is _____

Solution: Step 1: Understanding the 10-bit radiometric resolution.

In a 10-bit image, the number of possible Digital Numbers (DNs) ranges from 0 to $2^{10} - 1$. This is because a 10-bit resolution allows for 1024 distinct values, which range from 0 to 1023.

Step 2: Determining the maximum DN value.

The maximum DN value is equal to $2^{10} - 1$, which is:

$$2^{10} - 1 = 1024 - 1 = 1023$$

Therefore, the maximum DN value of the image is 1023.

Quick Tip

In an image with n-bit radiometric resolution, the maximum DN value is $2^n - 1$.

25. If one liter of water at pH 7 is mixed with one liter of water at pH 6, the resulting pH of the mixture is

Solution: Step 1: Understanding pH.

The pH scale is logarithmic and measures the concentration of hydrogen ions $[H^+]$. The formula for pH is:

$$\text{pH} = -\log[H^+]$$

Thus, a solution with pH 7 has a hydrogen ion concentration of $[H^+] = 10^{-7}$ mol/L, and a solution with pH 6 has $[H^+] = 10^{-6}$ mol/L.

Step 2: Mixing the two solutions.

When two solutions are mixed, the resulting concentration of $[H^+]$ is the average of the two concentrations, as the volumes are equal.

The combined concentration of hydrogen ions is:

$$[H^+]_{\text{mix}} = \frac{(10^{-7} + 10^{-6})}{2} = \frac{1.1 \times 10^{-6}}{2} = 5.5 \times 10^{-7}$$

Step 3: Calculating the resulting pH.

Now, we calculate the pH of the resulting solution:

$$\text{pH}_{\text{mix}} = -\log(5.5 \times 10^{-7}) = 6.26$$

Therefore, the resulting pH of the mixture is approximately 6.26.

Quick Tip

When mixing solutions with different pH values, remember that the resulting pH depends on the concentration of hydrogen ions in each solution.

---

26. A hillslope is shown below. If the area over the failure plane is 50 m^2 and the weight of the hillslope material (W) is 2000 tons, the Factor of Safety (FOS) for this hillslope in dry conditions is _____

Cohesion along failure plane = 196 kPa, **Dip of failure plane** = 60°, **Internal friction angle** = 30°, **Area over failure plane** = 50 m^2, **Weight of hillslope material** = 2000 tons **(Round off to two decimal places)**

Solution:

The formula for Factor of Safety (FOS) under dry conditions is:

$$\text{FOS} = \frac{cA + (W\cos\theta)\tan\phi}{W\sin\theta}$$

where:

$c = 196\,\text{kPa} = 196 \times 10^3\,\text{N/m}^2$

$A = 50\,\text{m}^2$

$W = 2000\,\text{tons} = 2000 \times 1000\,\text{kg} = 2 \times 10^6\,\text{kg}$

$g = 9.81\,\text{m/s}^2$

$\theta = 60^\circ$

$\phi = 30^\circ$

Step 1: Convert weight to Newtons:

$$W = 2 \times 10^6 \times 9.81 = 1.962 \times 10^7\,\text{N}$$

Step 2: Compute resisting forces:

$$cA = 196 \times 10^3 \times 50 = 9.8 \times 10^6\,\text{N}$$

$$(W\cos\theta)\tan\phi = (1.962 \times 10^7 \times \cos 60^\circ) \times \tan 30^\circ$$

$$= (1.962 \times 10^7 \times 0.5) \times 0.577 \approx 9.81 \times 10^6 \times 0.577 = 5.665 \times 10^6\,\text{N}$$

$$\text{Total resisting force} = 9.8 \times 10^6 + 5.665 \times 10^6 = 1.5465 \times 10^7\,\text{N}$$

Step 3: Compute driving force:

$$W\sin\theta = 1.962 \times 10^7 \times \sin 60^\circ = 1.962 \times 10^7 \times 0.866 \approx 1.699 \times 10^7\,\text{N}$$

Step 4: Compute FOS:

$$\text{FOS} = \frac{1.5465 \times 10^7}{1.699 \times 10^7} \approx 0.91$$

Quick Tip

The Factor of Safety (FOS) is a measure of slope stability. A value greater than 1 indicates a stable slope, and a value less than 1 suggests failure.

---

27. Which one of the following statements explains why elements Li, Be, and B have low cosmic abundance?

(A) These elements have low masses and hence, they break apart easily

(B) These elements have low binding energies which makes them unstable at high temperatures at the core of stars

(C) The low abundance of these elements is a unique feature of big stars with masses greater than 10 times that of our Sun

(D) These elements are highly reactive and hence, unstable

Correct Answer: (B) These elements have low binding energies which makes them unstable at high temperatures at the core of stars

Solution: Step 1: Understanding the cosmic abundance of elements.

Li, Be, and B are light elements that have low cosmic abundances. This is primarily due to their instability at high temperatures. The binding energies of their atomic nuclei are relatively low, meaning that at the extreme temperatures and pressures found in the cores of stars, these elements are more easily destroyed.

Step 2: Evaluating the options.

Option (A) is incorrect because the low masses of these elements do not directly lead to their low cosmic abundance; rather, it's their instability at high temperatures.

Option (B) is correct as it explains that the low binding energies of these elements cause them to be unstable at high stellar temperatures, preventing them from being abundantly formed.

Option (C) is incorrect because the low abundance of Li, Be, and B is not specific to large stars but is a general feature of the universe.

Option (D) is incorrect because while these elements are reactive, their low abundance is primarily due to nuclear instability rather than reactivity.

Quick Tip

Light elements like Li, Be, and B are rare in the universe because their nuclei are unstable at high temperatures, leading to their destruction in stellar interiors.

---

28. During a geochemical exploration survey in a hilly terrain, Cu concentration of stream sediments from a third order basin outlet was measured to be 3000 ppm. Considering a catchment area of 10 km^2 and a Cu background value of 200 ppm, which one of the following options is the productivity of this catchment for Cu?

(A) 1.5×10^6 m^2

(B) 2.8×10^6 m^2

(C) 3.0×10^6 m^2

(D) 3.2×10^6 m^2

Correct Answer: (B) 2.8×10^6 m^2

Solution: Step 1: Understanding productivity in geochemical surveys. The productivity of a catchment refers to the amount of a particular element (in this case, Cu) being contributed by the catchment area. It can be calculated using the formula:

$$\text{Productivity} = (\text{Cu concentration} - \text{background concentration}) \times \text{Catchment area}$$

Step 2: Applying the values. We are given: - Cu concentration = 3000 ppm - Background Cu concentration = 200 ppm - Catchment area = 10 km^2 = 10×10^6 m^2

Now, calculating the productivity:

$$\text{Productivity} = (3000 - 200) \times 10 \times 10^6 = 2800 \times 10^6 \text{ ppm·m}^2 = 2.8 \times 10^9 \text{ ppm·m}^2$$

Therefore, the productivity is 2.8×10^6 m^2, matching option (B).

Quick Tip

To calculate the productivity of an area for an element, subtract the background concentration from the measured concentration and multiply by the catchment area.

---

29. The combinations listed below represent major minerals observed in four igneous rocks:

(i) Olivine and Anorthite, (ii) K-feldspar and Quartz, (iii) Mg-Ca-pyroxene and Ca-Na-plagioclase, (iv) Amphibole and Na-Ca-plagioclase

Arrange these mineral combinations based on decreasing temperature of magma crystallization.

(A) $(i) > (ii) > (iii) > (iv)$

(B) $(i) > (iii) > (iv) > (ii)$

(C) $(i) > (iv) > (iii) > (ii)$

(D) $(ii) > (i) > (iv) > (iii)$

Correct Answer: (B) $(i) > (iii) > (iv) > (ii)$

Solution: Step 1: Understanding crystallization temperatures in igneous rocks.

The order in which minerals crystallize depends on their melting points, with minerals crystallizing at higher temperatures first.

Olivine and Anorthite: These minerals crystallize at the highest temperatures, making combination (i) the first in the sequence.

Mg-Ca-pyroxene and Ca-Na-plagioclase: These minerals crystallize at moderate temperatures and come after (i) in the sequence.

Amphibole and Na-Ca-plagioclase: These minerals crystallize at lower temperatures and come after (ii) in the sequence.

K-feldspar and Quartz: These minerals crystallize at the lowest temperatures, making combination (ii) last in the sequence.

Step 2: Arranging the mineral combinations.

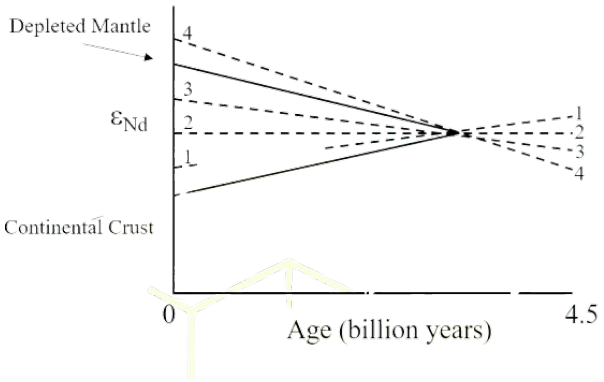
Based on their crystallization temperatures, the correct order is: (i) Olivine and Anorthite ¿ (iii) Mg-Ca-pyroxene and Ca-Na-plagioclase ¿ (iv) Amphibole and Na-Ca-plagioclase ¿ (ii) K-feldspar and Quartz.

Quick Tip

In igneous petrology, the order of crystallization follows the Bowen's reaction series, where minerals like olivine crystallize at the highest temperatures and minerals like quartz crystallize at the lowest.

---

30. Shown below is a schematic plot of ε_{Nd} (deviation of $^{143}Nd/^{144}Nd$ in a sample relative to CHUR) versus time. The two solid lines represent the evolution curves for the depleted mantle reservoir and the continental crust. Which one of the four dashed lines, marked 1, 2, 3, and 4, represents the evolution of the CHUR?



(A) Line 1

(B) Line 2

(C) Line 3

(D) Line 4

Correct Answer: (B) Line 2

Solution: Step 1: Understanding ε_{Nd} and its significance.

ε_{Nd} represents the deviation of the isotopic ratio $^{143}Nd/^{144}Nd$ from a standard, the CHUR (chondritic uniform reservoir). The evolution of ε_{Nd} over time provides insights into the differentiation of Earth's mantle and crust.

Step 2: Analyzing the evolution of the CHUR.

The CHUR line should show a relatively stable or slightly increasing trend with age, as it represents the isotopic composition of the primitive mantle and is often used as a baseline for comparison in geochemical studies. This line typically shows a gradual increase in ε_{Nd} as the mantle evolves over time.

Step 3: Interpreting the lines.

Line 1: This line likely represents the evolution of the continental crust, which typically shows more variation due to complex processes like crustal differentiation.

Line 2: This line exhibits a trend that closely follows the expected behavior for the CHUR, showing a steady or slightly increasing ε_{Nd} with age.

Line 3 and Line 4: These lines deviate more drastically, which could indicate other reservoirs, such as the depleted mantle, which exhibits different isotopic behavior.

Quick Tip

In isotopic studies, the CHUR line typically represents the baseline isotopic composition of the Earth's primitive mantle, showing a steady or slightly increasing trend over time.

---

31. Which one of the following expressions represents porosity of a rock?

(A) $\frac{\text{Solid volume – Pore volume}}{\text{Solid volume}}$

(B) $\frac{\text{Bulk volume – Pore volume}}{\text{Bulk volume}}$

(C) $\frac{\text{Bulk volume – Solid volume}}{\text{Solid volume}}$

(D) $\frac{\text{Bulk volume – Solid volume}}{\text{Bulk volume}}$

Correct Answer: (D) $\frac{\text{Bulk volume – Solid volume}}{\text{Bulk volume}}$

Solution:

Porosity is the ratio of the pore volume to the bulk volume of the rock. The expression for porosity ϕ is given by:

$$\phi = \frac{\text{Pore volume}}{\text{Bulk volume}} = 1 - \frac{\text{Solid volume}}{\text{Bulk volume}}$$

Thus, the correct formula for porosity is:

$$\text{Porosity} = \frac{\text{Bulk volume – Solid volume}}{\text{Bulk volume}}$$

Quick Tip

Porosity is a critical parameter in geology, particularly for understanding fluid storage in rocks.

---

32. Choose the correct option where both organisms do NOT secrete any $CaCO_3$ (calcite or aragonite).

(A) Foraminifera and Coccolithophore

(B) Diatom and Radiolaria

(C) Diatoms and Corals

(D) Foraminifera and Radiolaria

Correct Answer: (B) Diatom and Radiolaria

Solution:

Foraminifera: These organisms secrete calcium carbonate ($CaCO_3$).

Coccolithophore: These organisms also secrete calcium carbonate ($CaCO_3$).

Diatoms: Diatoms do not secrete calcium carbonate. Instead, they secrete silica (SiO_2).

Radiolaria: Radiolaria do not secrete calcium carbonate either; they secrete silica.

Thus, the correct answer is (B) Diatom and Radiolaria, as neither of these organisms secrete $CaCO_3$.

Quick Tip

Diatoms and Radiolaria are siliceous organisms, meaning they form skeletons out of silica instead of calcium carbonate.

---

33. From the following optical properties of minerals, select an appropriate option to identify the direction of analyzer and polarizer if the available microscope is without a cross-hair.

(A) Pleochroism of common hornblende

(B) Extinction of diopside

(C) Extinction of glaucophane

(D) Pleochroism of biotite

Correct Answer: (D) Pleochroism of biotite

Solution:

Pleochroism refers to the ability of a mineral to change color as it is rotated under polarized light. In minerals like biotite, pleochroism can be used to determine the orientation of the polarizer and analyzer.

For minerals like biotite, which exhibit strong pleochroism, it is possible to determine the direction of the analyzer and polarizer by observing the color changes under different orientations, even without a cross-hair.

Step 2: Conclusion Option (D) is correct, as pleochroism of biotite helps identify the correct orientation of the analyzer and polarizer.

Quick Tip

Pleochroism can help in determining the orientation of the mineral under polarized light when a cross-hair is unavailable.

---

34. Which one of the following minerals has crystallographic axes $a_1 = a_2 \neq c$ and all interaxial angles equal to 90°?

(A) Beryl

(B) Barite

(C) Plagioclase

(D) Zircon

Correct Answer: (D) Zircon

Solution:

The crystallographic structure described in the question corresponds to a tetragonal system, where:

$a_1 = a_2 \neq c$

All interaxial angles are 90°.

Among the listed minerals:

Beryl: Has an hexagonal crystal system.

Barite: Has an orthorhombic system, not tetragonal.

Plagioclase: Belongs to the triclinic system.

Zircon: Has a tetragonal crystal system with $a_1 = a_2 \neq c$ and interaxial angles of 90°.

Step 2: Conclusion

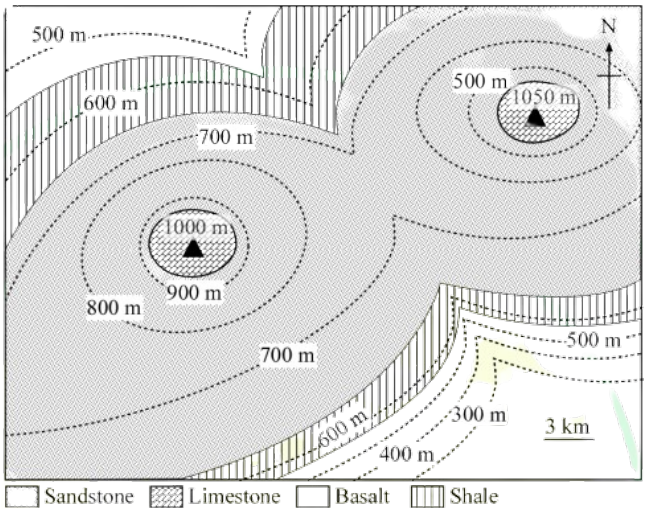
Option (D) Zircon is the correct answer, as it fits the conditions of the tetragonal system described.

Quick Tip

Understanding crystal systems and their symmetry is essential for identifying minerals based on their crystallographic axes and angles.

---

35. Which one of the following statements correctly describes the features in the geological map?



(A) Horizontal sedimentary beds above a basalt basement

(B) Anticline consisting of sedimentary rocks and basalt

(C) Syncline consisting of sedimentary rocks and basalt

(D) Steep south-dipping sedimentary beds above a basalt basement

Correct Answer: (A) Horizontal sedimentary beds above a basalt basement

Solution: Step 1: Interpreting the geological map.

The map shows a series of sedimentary layers (sandstone, limestone, shale) that are positioned above a basalt basement. The layers are relatively flat, indicating horizontal

bedding. The basalt appears to form the lower part of the sequence, with the sedimentary rocks lying above it.

Step 2: Evaluating the options.

Option (A) is correct as it correctly describes horizontal sedimentary beds above the basalt basement. The map shows no evidence of folding, so the sedimentary layers are interpreted as being horizontal.

Option (B) is incorrect because the map shows no folding or anticline structure.

Option (C) is incorrect because there is no evidence of synclinal folding in the map.

Option (D) is incorrect as the layers are not steeply dipping, but rather appear to be horizontal.

Quick Tip

When interpreting geological maps, look for the shape and orientation of the layers. Horizontal beds suggest undisturbed sedimentary rocks, often lying above older rock formations like basalt.

---

36. In which one of the following rivers does helical flow play an important role in controlling river dynamics and channel morphology?

(A) Meandering rivers

(B) Straight rivers

(C) Braided rivers

(D) Bedrock rivers

Correct Answer: (A) Meandering rivers

Solution:

Helical flow refers to the spiral movement of water in a river, which plays a significant role in shaping the channel morphology. This type of flow is primarily observed in meandering rivers, where the flow exhibits a curving motion around bends. The helical flow helps in the transport of sediment, the erosion of outer banks, and the deposition of sediment on inner banks, thus significantly influencing the river dynamics and morphology.

Step 2: Conclusion

Option (A) Meandering rivers is the correct answer because helical flow plays a major role in shaping the dynamics and morphology of meandering rivers.

Quick Tip

Helical flow in meandering rivers helps to shape channel features like point bars and cut banks by influencing erosion and sediment deposition.

---

37. Which of the following statements is/are NOT correct for stratigraphy of the Himalaya?

(A) Tethyan Sedimentary Sequence rocks are of Precambrian age

(B) The Lesser Himalayan Sequence rocks are younger than the Higher Himalayan Crystallines

(C) The Sub-Himalayan Sequence rocks are younger than the Lesser Himalayan rocks

(D) Collisional Himalayan orogeny occurred in the Cenozoic Era

Correct Answer: (A) Tethyan Sedimentary Sequence rocks are of Precambrian age, (B) The Lesser Himalayan Sequence rocks are younger than the Higher Himalayan Crystallines

Solution:

Tethyan Sedimentary Sequence rocks: These rocks are not of Precambrian age. Instead, they are primarily Mesozoic and Cenozoic in age, deposited in the Tethys Sea.

Lesser Himalayan Sequence rocks: These rocks are older than the Higher Himalayan Crystallines, as the latter consists of the older crystalline rocks. So, the statement in option (B) is also incorrect.

Sub-Himalayan Sequence rocks: These rocks are indeed younger than the Lesser Himalayan rocks, making option (C) correct.

Collisional Himalayan orogeny: This occurred during the Cenozoic Era, marking the collision of the Indian Plate with the Eurasian Plate and the rise of the Himalayan range.

Step 2: Conclusion

Options (A) and (B) are NOT correct, as Tethyan Sedimentary Sequence rocks are not of Precambrian age, and the Lesser Himalayan rocks are older than the Higher Himalayan Crystallines.

Quick Tip

Understanding the geologic history of the Himalayas helps clarify the stratigraphic sequence and age relationships of various rock units.

---

38. Which of the following factors will REDUCE the chances of landslide failure?

(A) Increase in shear stress

(B) Increase in water content of pore spaces

(C) Increase in angle of internal friction

(D) Increase in cohesion of soil grains

Correct Answer: (C) Increase in angle of internal friction, (D) Increase in cohesion of soil grains

Solution:

Landslides occur when the resisting forces are overcome by the driving forces. The following factors reduce the chances of landslide failure:

Increase in shear stress: This would increase the likelihood of landslide failure by promoting sliding.

Increase in water content of pore spaces: Water reduces soil cohesion, making the material more susceptible to sliding, thereby increasing the chance of landslide failure.

Increase in angle of internal friction: This would reduce the chances of landslide failure, as it increases the resistance of the soil to sliding.

Increase in cohesion of soil grains: This would also reduce the chances of landslide failure, as stronger cohesion means greater resistance to sliding.

Step 2: Conclusion

Options (C) and (D) are correct, as increasing the angle of internal friction and the cohesion of soil grains will help reduce the chances of landslide failure.

Quick Tip

The angle of internal friction and cohesion of soil grains are key factors that determine the stability of slopes. Higher friction and cohesion enhance slope stability and reduce the risk of landslides.

---

39. Which of the following rock and texture combinations is/are CORRECT?

(A) Komatiite and Spinifex

(B) Gabbro and Ophitic

(C) Marble and Granoblastic

(D) Basalt and Porphyroblastic

Correct Answer: (A) Komatiite and Spinifex, (B) Gabbro and Ophitic, (C) Marble and Granoblastic

Solution: Evaluating the rock and texture combinations.

Komatiite and Spinifex: Komatiite is a type of ultramafic volcanic rock, and Spinifex texture is characteristic of komatiites, formed by the crystallization of olivine in high-temperature lava. This combination is correct.

Gabbro and Ophitic: Gabbro is an intrusive mafic rock, and Ophitic texture, where large crystals of pyroxene enclose smaller crystals of plagioclase, is typical of gabbro. This combination is correct.

Marble and Granoblastic: Marble, a metamorphic rock formed from limestone, commonly has a granoblastic texture, which is typical for rocks that have undergone recrystallization during metamorphism. This combination is correct.

Basalt and Porphyroblastic: Basalt is an extrusive igneous rock that typically exhibits a fine-grained texture, not a porphyroblastic texture, which is characteristic of metamorphic rocks. This combination is incorrect.

Quick Tip

When identifying textures in rocks, remember that certain textures, like Spinifex, Ophitic, and Granoblastic, are characteristic of specific rock types such as komatiite, gabbro, and marble.

---

40. Which of the following statements regarding marine organisms is/are NOT true?

(A) Foraminifera are multicellular marine organisms

(B) Sponges form their spicules with silica

(C) Coccolithophores are sea-surface dwelling organisms

(D) Species diversity of benthic foraminifera is less than that of planktonic foraminifera

Correct Answer: (A) Foraminifera are multicellular marine organisms, (D) Species diversity of benthic foraminifera is less than that of planktonic foraminifera

Solution: Analyzing the statements.

Option (A): Foraminifera are single-celled marine organisms, not multicellular. This statement is NOT true.

Option (B): Sponges do form their spicules with silica, especially in siliceous sponges. This statement is true.

Option (C): Coccolithophores are indeed sea-surface dwelling organisms, as they are planktonic and live near the surface of the ocean. This statement is true.

Option (D): The species diversity of planktonic foraminifera is generally greater than that of benthic foraminifera. Therefore, this statement is NOT true.

Quick Tip

Foraminifera are unicellular organisms, and benthic foraminifera tend to have less species diversity compared to planktonic foraminifera due to environmental factors.

---

41. Which of the following rocks is/are characteristic of fossil subduction zones?

(A) Wollastonite and scapolite bearing skarn

(B) Andalusite and staurolite bearing hornfels

(C) Garnet and glaucophane bearing blueschist

(D) Garnet and omphacite bearing eclogite

Correct Answer: (C) Garnet and glaucophane bearing blueschist, (D) Garnet and omphacite bearing eclogite

Solution:

Step 1: Understanding subduction zones

Subduction zones are areas where one tectonic plate moves beneath another. These zones are characterized by high-pressure, low-temperature conditions, which lead to the formation of distinct metamorphic rocks. The minerals formed in these environments are key indicators of subduction-related processes.

Step 2: Rock Types and Their Association with Subduction Zones Let's examine each option:

(A) Wollastonite and scapolite bearing skarn:

Skarn is a rock formed by the interaction of limestone or dolomite with magma. It typically forms during contact metamorphism, not in subduction zones. Wollastonite and scapolite are associated with these conditions but are not characteristic of subduction zones.

(B) Andalusite and staurolite bearing hornfels:

Hornfels forms due to contact metamorphism, typically when rocks are heated by an intruding magma body. It is not associated with subduction zones. Andalusite and staurolite are typically formed at higher temperatures, under lower-pressure conditions, so this rock type is not characteristic of subduction zones either.

(C) Garnet and glaucophane bearing blueschist:

Blueschist forms in high-pressure, low-temperature conditions, which are characteristic of subduction zones. The presence of garnet and glaucophane in blueschist is a classic indicator of a subduction environment.

(D) Garnet and omphacite bearing eclogite:

Eclogite is also a high-pressure rock that forms at even greater depths than blueschist, making it characteristic of subduction zones. The minerals garnet and omphacite are commonly found in eclogite, which forms deeper within the subduction zone.

Step 3: Conclusion

Options (C) and (D) are correct because both blueschist and eclogite are characteristic of

subduction zones, with garnet and glaucophane present in blueschist and garnet and omphacite in eclogite.

Quick Tip

Blueschist and eclogite are key metamorphic rocks that form in subduction zones, representing high-pressure, low-temperature conditions.

---

42. Compared to Fe, Mg, and Ca, the content of K is extremely low in igneous clinopyroxene. Which of the following CANNOT explain its low abundance?

(A) K^+ has a larger ionic radius than Fe^{2+}, Mg^{2+}, and Ca^{2+}

(B) K is incompatible and hence, enriched in the continental crust

(C) K is fluid mobile and hence, easily leached out of clinopyroxene

(D) K has multiple oxidation states

Correct Answer: (B) K is incompatible and hence, enriched in the continental crust, (C) K is fluid mobile and hence, easily leached out of clinopyroxene, (D) K has multiple oxidation states

Solution:

Step 1: Understanding why K is low in clinopyroxene

Potassium (K) has a relatively low concentration in igneous clinopyroxene compared to other cations such as Fe, Mg, and Ca. Let's look at the reasons:

(A) K^+ has a larger ionic radius than Fe^{2+}, Mg^{2+}, and Ca^{2+}:

This is a valid reason. Potassium (K^+) has a larger ionic radius compared to Fe^{2+}, Mg^{2+}, and Ca^{2+}, making it less compatible in the clinopyroxene structure. Minerals like clinopyroxene prefer smaller cations to fit into their crystal structure, which is why K is present in low amounts.

(B) K is incompatible and hence, enriched in the continental crust:

This statement is incorrect. K is indeed incompatible during crystallization, but it does not become enriched in the continental crust due to this incompatibility. Instead, it remains in the melt during crystallization, meaning that it is less likely to be incorporated into clinopyroxene. This is one of the reasons for its low abundance in clinopyroxene.

(C) K is fluid mobile and hence, easily leached out of clinopyroxene:
Potassium is mobile in fluids and can be leached from minerals like clinopyroxene over time, further reducing its concentration. This is a valid reason for the low abundance of K in clinopyroxene.
(D) K has multiple oxidation states:
This statement is incorrect because potassium (K) typically exists in only one oxidation state, K^+, and does not exhibit multiple oxidation states. This factor does not affect its low abundance in clinopyroxene.
Step 2: Conclusion Options (B), (C), and (D) are the correct answers, as these factors contribute to the low abundance of K in clinopyroxene.

Quick Tip

Understanding the ionic radii, fluid mobility, and behavior of elements in crystallization processes is key to explaining their presence or absence in minerals.

---

43. The sediment yield at the outlet of a river having a catchment area of 8 km^2 is 6000 tons/year. If the sediment density is 1.5 g/cm^3, the average erosion rate of the river basin is _____ mm/yr.
Solution: Step 1: Understanding the given data.
Sediment yield = 6000 tons/year
Catchment area = 8 km^2
Sediment density = 1.5 g/cm^3
We need to calculate the erosion rate in mm/year. First, we need to convert the sediment yield into volume, then divide it by the catchment area to get the erosion rate.
Step 2: Converting tons to grams.
Since 1 ton = 10^6 grams, the sediment yield in grams per year is:

$$6000\,\text{tons/year} = 6000 \times 10^6\,\text{grams/year}$$

Step 3: Converting sediment density to compatible units. The density is given as 1.5 g/cm^3, and we need to convert it to kg/m^3:

$$1.5\,\text{g/cm}^3 = 1500\,\text{kg/m}^3$$

Step 4: Calculating the sediment volume.

The volume of sediment can be found using the formula:

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{6000 \times 10^6\,\text{grams/year}}{1.5\,\text{g/cm}^3} = 4000 \times 10^6\,\text{cm}^3/\text{year}$$

Now, convert the volume to cubic meters:

$$4000 \times 10^6\,\text{cm}^3/\text{year} = 4000\,\text{m}^3/\text{year}$$

Step 5: Calculating the erosion rate.

The catchment area is 8 km^2 = 8×10^6 m^2. The erosion rate is:

$$\text{Erosion rate} = \frac{\text{Volume}}{\text{Area}} = \frac{4000\,\text{m}^3/\text{year}}{8 \times 10^6\,\text{m}^2} = 0.0005\,\text{m/year} = 0.5\,\text{mm/year}$$

Thus, the average erosion rate is 0.50 mm/year.

Quick Tip

To calculate the erosion rate, first convert sediment yield into volume using sediment density, then divide by the catchment area to get the rate in units of depth per year.

---

44. In a hypothetical rock, the Kd values of element E in minerals M1, M2, and M3 are 1.5, 1.0, and 0.5, respectively. The modal abundances of M1, M2, and M3 are 10%, 40%, and 50%, respectively. The bulk partition coefficient of element E in this rock is

---

Solution: Step 1: Understanding the formula for the bulk partition coefficient.

The bulk partition coefficient (K_d) for the rock is calculated as a weighted average based on the modal abundances and the partition coefficients of each mineral:

$$K_{\text{bulk}} = (f_1 \times K_{d1}) + (f_2 \times K_{d2}) + (f_3 \times K_{d3})$$

Where:

f_1, f_2, f_3 are the modal abundances of M1, M2, and M3, respectively.

K_{d1}, K_{d2}, K_{d3} are the partition coefficients of element E in M1, M2, and M3, respectively.

Step 2: Applying the values.

Given:

$K_{d1} = 1.5, K_{d2} = 1.0, K_{d3} = 0.5$

$f_1 = 10\% = 0.1, f_2 = 40\% = 0.4, f_3 = 50\% = 0.5$

The bulk partition coefficient is:

$$K_{\text{bulk}} = (0.1 \times 1.5) + (0.4 \times 1.0) + (0.5 \times 0.5) = 0.15 + 0.4 + 0.25 = 0.8$$

Thus, the bulk partition coefficient of element E in the rock is 0.80.

Quick Tip

To calculate the bulk partition coefficient, take the weighted average of the individual partition coefficients based on the modal abundances of the minerals.

---

45. A particular Index of Alteration (IA) is defined as the molar concentration ratio (expressed as weight percentage) of fluid immobile element(s) to fluid mobile element(s) and is expressed by $100 \times \left(\frac{[Al_2O_3]}{[Al_2O_3]+[Na_2O]+[K_2O]}\right)$. For chemical weathering of silicate rocks, which one of the following statements is correct?

(A) High IA values (> 85) indicate intense chemical weathering

(B) Low IA values (> 15) indicate intense chemical weathering

(C) The IA values do not vary for silicate rocks

(D) The minimum IA value for an unweathered granite is 0

Correct Answer: (A) High IA values (> 85) indicate intense chemical weathering

Solution: Step 1: Understanding the Index of Alteration (IA).

The IA value measures the relative concentration of immobile elements (like Al_2O_3) versus mobile elements (like Na_2O and K_2O) during the chemical weathering process. A high IA value suggests that immobile elements have been preferentially retained during weathering, indicating a high degree of chemical weathering.

Step 2: Evaluating the options.

Option (A) is correct because high IA values (greater than 85) are indicative of intense weathering, where a large proportion of mobile elements (Na_2O and K_2O) have been removed, and immobile elements (Al_2O_3) dominate.
Option (B) is incorrect because low IA values (¡ 15) would suggest little to no weathering, where the mobile elements are still abundant.
Option (C) is incorrect because IA values do vary significantly with the degree of weathering and the type of rock.
Option (D) is incorrect because even an unweathered granite would have an IA value greater than 0, given that some immobile elements are always present.

Quick Tip

The IA index is a useful indicator of weathering intensity, where high values indicate intense weathering and low values suggest minimal alteration.

---

46. What is the value of the maximum shear stress in a rock, for which the state of stress is given by the following Mohr circle?

(A) 20 MPa

(B) 40 MPa

(C) 50 MPa

(D) 60 MPa

Correct Answer: (A) 20 MPa

Solution:

To determine the maximum shear stress from the Mohr circle, we can use the following relation:

$$\tau_{\text{max}} = \frac{\sigma_1 - \sigma_3}{2}$$

Where:

$\sigma_1 = 50\,\text{MPa}$ (major principal stress),

$\sigma_3 = 10\,\text{MPa}$ (minor principal stress).

Step 1: Apply the formula

Substituting the values into the formula for maximum shear stress:

$$\tau_{\text{max}} = \frac{50\,\text{MPa} - 10\,\text{MPa}}{2} = \frac{40\,\text{MPa}}{2} = 20\,\text{MPa}$$

Step 2: Conclusion

The maximum shear stress is $20\,\text{MPa}$.

Quick Tip

The maximum shear stress corresponds to the radius of the Mohr's circle and is calculated as half the difference between the maximum and minimum principal stresses.

---

47. In a hypothetical scenario, the element Y has 4 stable isotopes ^{197}Y, ^{198}Y, ^{199}Y, and ^{200}Y. The isotope ^{199}Y is radiogenic and is formed by β^--decay of the isotope ^{199}X of the element X with a half-life of 3.51 billion years. An igneous rock, which has behaved as a closed system, has three different minerals P, Q, and R, which crystallized from the same magma 2 billion years ago, with initial X/Y ratios of 1.75, 2.05, and 0.75, respectively. Which one of the following statements is true for the ratio ^{199}Y/^{200}Y in this igneous rock in the present day?

(A) $P > Q > R$

(B) $R > P > Q$

(C) $Q > P > R$

(D) $Q > R > P$

Correct Answer: (C) $Q > P > R$

Solution: Step 1: Understanding the scenario.

The isotopic ratio $\frac{199Y}{200Y}$ in the rock will depend on the initial X/Y ratio and the radiogenic decay of the isotope 199X to 199Y. Over time, the radiogenic 199Y will accumulate in minerals based on the initial X/Y ratio and the time that has passed since the rock crystallized.

Step 2: Evaluating the initial X/Y ratios.

Mineral P has the highest initial X/Y ratio (1.75), meaning it initially contained more of element X relative to Y, so it would have accumulated more of the radiogenic 199Y.

Mineral Q has a moderate initial X/Y ratio (2.05), which is slightly higher than R but lower than P, meaning it will accumulate less of the radiogenic 199Y compared to P.
Mineral R has the lowest initial X/Y ratio (0.75), meaning it had less of element X initially, and therefore it would accumulate the least amount of radiogenic 199Y.

Step 3: Considering radiogenic decay and the time elapsed.

Given that all the minerals crystallized 2 billion years ago, the rate of accumulation of 199Y in each mineral is proportional to the initial X/Y ratio, but since the time is the same for all, the mineral with the highest initial X/Y ratio (P) would have the highest 199Y/200Y ratio, followed by Q, and R with the lowest.

Step 4: Correct interpretation of the ratio.

After 2 billion years, the correct order of 199Y/200Y ratio in the minerals would be: Q ¿ P ¿ R, based on the initial X/Y ratios and the corresponding amount of 199Y formed.

Quick Tip

In isotopic systems with radiogenic decay, minerals with a higher initial parent/daughter ratio accumulate more radiogenic daughter isotopes over time, resulting in higher current daughter/parent ratios.

---

48. Which one of the following factors governs the inclination of the slip face (leeward side) of ripples?

(A) Velocity of the transporting medium

(B) Sediment supply

(C) Internal friction angle

(D) Drag force

Correct Answer: (C) Internal friction angle

Solution: Step 1: Understanding the formation of ripples.

Ripples are formed by the movement of fluid (wind or water) over loose sediments, creating a series of undulations. The inclination of the slip face (the leeward side) of the ripple is influenced by the friction between the grains on the surface of the sediment.

Step 2: Evaluating the options.

Option (A) is incorrect because while the velocity of the transporting medium influences ripple formation, it does not directly control the inclination of the slip face.
Option (B) is incorrect because sediment supply influences ripple height but does not control the slip face inclination.
Option (C) is correct as the internal friction angle of the sediment governs the angle at which the slip face of the ripple forms. Higher friction results in steeper slip faces.
Option (D) is incorrect because drag force is more important for sediment transport but does not directly control the inclination of the slip face.

Quick Tip

The internal friction angle of sediment controls the angle of repose on the slip face of ripples. A higher friction angle results in a steeper slip face.

---

49. High intensity rainfall in the Higher Himalayan region causes extensive damage, because of its large droplet size. Which one of the following relationships between the kinetic energy of raindrop (E) and droplet diameter (D) explains this process?

(A) $E \propto D^{1/2}$

(B) $E \propto D^2$

(C) $E \propto D^3$

(D) $E \propto D^4$

Correct Answer: (D) $E \propto D^4$

Solution: Step 1: Understanding the relationship between kinetic energy and droplet size.

The kinetic energy (E) of a raindrop is proportional to the mass of the droplet and the square of its velocity. Since the mass of a raindrop is proportional to the volume, and volume is proportional to D^3 (where D is the diameter), the kinetic energy increases with the fourth power of the droplet diameter, $E \propto D^4$.

Step 2: Evaluating the options.

Option (A) is incorrect because $E \propto D^{1/2}$ would imply a square root relationship between energy and droplet size, which is not correct.

Option (B) is incorrect because $E \propto D^2$ implies a quadratic relationship, which does not apply to the kinetic energy of raindrops.

Option (C) is incorrect because $E \propto D^3$ implies that energy increases with the cube of the droplet size, which is not the correct relationship.

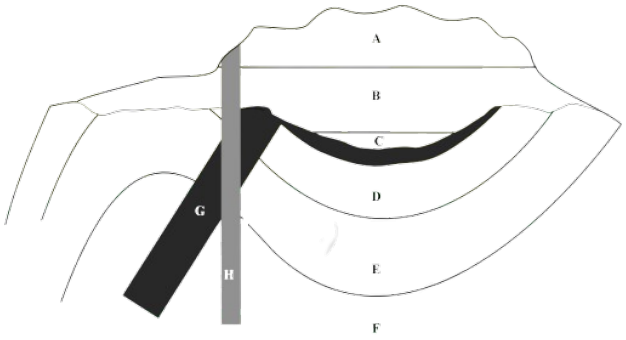
Option (D) is correct because the kinetic energy of a raindrop is proportional to the fourth power of its diameter, as both mass and velocity depend on the size of the droplet.

Quick Tip

The kinetic energy of a raindrop increases significantly with its size, as larger droplets have much greater energy and potential for causing damage during high-intensity rainfall.

---

50. The units A to H marked on the figure represent different rock formations. Select the option that describes the chronological sequence from old to young.



(A) F, E, D, G, C, B, A, H

(B) F, E, D, C, B, A, G, H

(C) F, E, D, C, H, B, A

(D) F, E, D, H, G, C, B, A

Correct Answer: (A) F, E, D, G, C, B, A, H

Solution:

Step 1: Analyze the diagram

In the diagram:

The units are arranged with layers overlapping and faulting.

The sequence is determined by the position of the units, with the oldest at the bottom and the

youngest at the top.

Step 2: Identify the correct sequence

Based on the figure, the chronological order starting from the oldest layer (at the bottom) is:

F is the oldest layer.

E comes next, as it is above F.

D follows E.

G comes after D, as it is above it.

C follows G.

B follows C.

A is above B.

H is the youngest layer, lying above all others.

Step 3: Conclusion

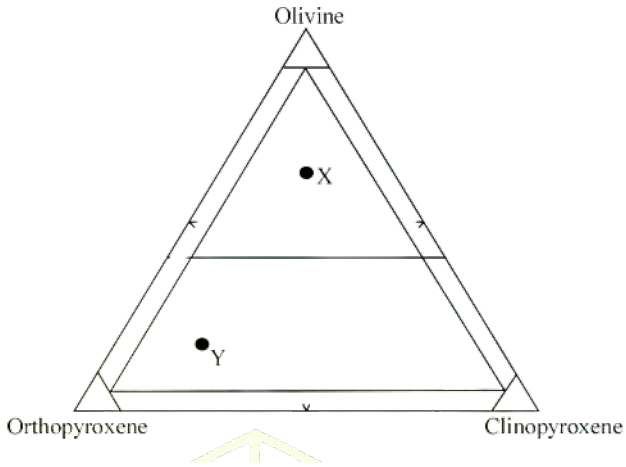
The correct chronological sequence from old to young is F, E, D, G, C, B, A, H, which corresponds to Option (A).

Quick Tip

When interpreting a geological sequence, always follow the law of superposition to determine the order of deposition, starting with the oldest layer at the bottom.

---

51. In the IUGS classification diagram for mafic and ultramafic rocks shown below, choose the correct option for the rocks labelled X and Y.



(A) X: Harzburgite and Y: Olivine Webstite

(B) X: Lherzolite and Y: Olivine Webstite

(C) X: Dunite and Y: Clinopyroxenite

(D) X: Anorthosite and Y: Wehrlite

Correct Answer: (B) X: Lherzolite and Y: Olivine Webstite

Solution: Step 1: Interpreting the IUGS classification diagram.

In the IUGS classification diagram, the relative positions of the rock compositions are determined by the proportion of Olivine, Orthopyroxene, and Clinopyroxene.

Lherzolite: Lherzolite is a rock made up of olivine, orthopyroxene, and clinopyroxene, typically with a higher proportion of orthopyroxene and clinopyroxene. The rock ”X” in the diagram is positioned toward the olivine-orthopyroxene side, fitting the composition of Lherzolite.

Olivine Webstite: This rock is primarily composed of olivine, with some clinopyroxene. The rock ”Y” is positioned near the olivine axis but has a notable presence of clinopyroxene, consistent with Olivine Webstite.

Step 2: Evaluating the options.

Option (A) is incorrect because Harzburgite typically has a high concentration of orthopyroxene, but ”X” is closer to the olivine-orthopyroxene boundary.

Option (B) is correct because ”X” is positioned in the region for Lherzolite and ”Y” is in the region for Olivine Webstite.

Option (C) is incorrect because Dunite is predominantly olivine, and ”X” contains both olivine and orthopyroxene, so it is not consistent with Dunite.

Option (D) is incorrect because Anorthosite is a plagioclase-rich rock and does not fit the diagram, and Wehrlite is not correctly positioned either.

Quick Tip

In the IUGS classification diagram, the rocks are classified based on their relative content of olivine, orthopyroxene, and clinopyroxene. Lherzolite contains a combination of all three, and Olivine Webstite is dominated by olivine with some clinopyroxene.

---

52. Choose the correct combination of minerals (listed in Group A) with the

corresponding locations of their deposits (listed in Group B).

Group-A	Group-B
M. Magnesite	1. Bikaner
N. Uraninite	2. Nausahi
O. Clay minerals	3. Salem
P. Platinum group elements	4. Jaduguda

(A) M-1; N-2; O-3; P-4

(B) M-4; N-3; O-2; P-1

(C) M-3; N-4; O-1; P-2

(D) M-2; N-4; O-1; P-3

Correct Answer: (C) M-3; N-4; O-1; P-2

Solution:

Step 1: Identify the locations for each mineral deposit

Magnesite (M) is found in Salem, Tamil Nadu.

Uraninite (N) is found in Jaduguda, Jharkhand.

Clay minerals (O) are found in Bikaner, Rajasthan.

Platinum group elements (P) are found in Nausahi, Odisha.

Step 2: Conclusion

The correct combination of minerals and their corresponding locations is (C) M-3; N-4; O-1; P-2.

Quick Tip

Understanding the geological distribution of minerals helps in identifying their deposits and their potential applications in industry.

---

53. Choose the explanation(s) for negative Eu anomalies in upper crustal rocks like granite and granodiorite.

(A) These rocks are end-products of magmatic differentiation

(B) These rocks were formed by melting of the mantle, which was already depleted in Eu

(C) Most of the Eu was incorporated in other minerals

(D) The melt residues contain plagioclase which are enriched in Eu

Correct Answer: (A) These rocks are end-products of magmatic differentiation, (D) The melt residues contain plagioclase which are enriched in Eu

Solution:

Step 1: Explanation of negative Eu anomalies

Negative europium (Eu) anomalies in upper crustal rocks like granite and granodiorite are primarily due to the depletion of Eu during the magmatic process:

(A) These rocks are end-products of magmatic differentiation: This is correct because during magmatic differentiation, Eu is preferentially incorporated into plagioclase, leading to a depletion of Eu in the melt.

(B) These rocks were formed by melting of the mantle, which was already depleted in Eu: This is incorrect because the depletion of Eu in granite and granodiorite is due to crystallization processes, not because the mantle was initially depleted in Eu.

(C) Most of the Eu was incorporated in other minerals: This is partially correct, but the main reason for the Eu anomaly is the preference of Eu for plagioclase over other minerals.

(D) The melt residues contain plagioclase which are enriched in Eu: This is correct. Plagioclase crystallizes early in the process and incorporates Eu, which causes the negative Eu anomaly in the residual melt.

Step 2: Conclusion

The correct explanations for negative Eu anomalies in rocks like granite and granodiorite are (A) and (D).

Quick Tip

Negative Eu anomalies are key indicators of magmatic processes and can be used to infer the history of magmatic differentiation and crystallization.

---

54. Which characteristic feature(s) best explain(s) the HIMU mantle reservoir?

(A) Magmas derived from this reservoir have high 208Pb/204Pb and 206Pb/204Pb

(B) Magmas derived from this reservoir have high 207Pb/204Pb and 206Pb/204Pb

(C) This reservoir has evolved with high Th/U

(D) This reservoir has evolved with high U/Pb

Correct Answer: (B) Magmas derived from this reservoir have high 207Pb/204Pb and 206Pb/204Pb, (D) This reservoir has evolved with high U/Pb

Solution:

Step 1: Understanding the HIMU mantle reservoir

The HIMU (High-μ) mantle reservoir is characterized by specific isotopic features:

(A) Magmas derived from this reservoir have high 208Pb/204Pb and 206Pb/204Pb: This is incorrect. The HIMU reservoir is characterized by high ratios of 207Pb/204Pb and 206Pb/204Pb, not 208Pb.

(B) Magmas derived from this reservoir have high 207Pb/204Pb and 206Pb/204Pb: This is correct. HIMU is characterized by high 207Pb/204Pb and 206Pb/204Pb ratios, which reflect the enrichment of the source in radiogenic lead.

(C) This reservoir has evolved with high Th/U: This is incorrect. The HIMU reservoir is known for having a high U/Pb ratio, not necessarily a high Th/U ratio.

(D) This reservoir has evolved with high U/Pb: This is correct. The HIMU reservoir is known for having a high U/Pb ratio, reflecting its source's enrichment in uranium relative to lead.

Step 2: Conclusion

The correct explanations for the HIMU mantle reservoir are (B) and (D).

Quick Tip

The HIMU mantle reservoir is an important feature in understanding mantle dynamics and the isotopic evolution of Earth's mantle, particularly in oceanic basalts.

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55. Choose the correct option(s) related to tectonic settings and associated rock types.

(A) Tholeiitic basalts and alkali basalts are both associated with mid-oceanic ridges

(B) Andesites are commonly found in convergent plate boundaries

(C) Tholeiitic basalts and alkali basalts can both be associated with plume-related volcanism

(D) Volcanic rocks from subduction zones have high volatile content

Correct Answer: (B) Andesites are commonly found in convergent plate boundaries, (C)

Tholeiitic basalts and alkali basalts can both be associated with plume-related volcanism, (D) Volcanic rocks from subduction zones have high volatile content

Solution: Analyzing the options.

Option (A) is incorrect because Tholeiitic basalts are typically associated with divergent plate boundaries (e.g., mid-oceanic ridges), whereas alkali basalts are more commonly associated with hotspot or plume-related volcanism, not mid-ocean ridges.

Option (B) is correct because Andesites are commonly found at convergent plate boundaries, especially in subduction zones where magma is generated from the subduction of oceanic plates beneath continental plates.

Option (C) is correct because both Tholeiitic basalts and alkali basalts can be found in regions related to mantle plumes, such as hotspots, where magmas are derived from deep mantle material.

Option (D) is correct because volcanic rocks formed in subduction zones tend to have a high volatile content, as water and other volatiles are released from the subducting plate and incorporated into the overlying magma.

Quick Tip

Volcanic rocks formed in different tectonic settings have distinct compositions. Tholeiitic basalts are associated with divergent boundaries, while andesites and high-volatile volcanic rocks are common in subduction zones.

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56. Which of the following options is/are correct for movement of warm-base glaciers?

(A) Movement is dominated by basal sliding

(B) Internal deformation involving slippage within and between ice crystals leads to glacial movement

(C) Internal deformation is governed by shear stress following Power Law

(D) Vertical profile of glacier flow velocity is maximum at the base and decreases upwards

Correct Answer: (A) Movement is dominated by basal sliding, (B) Internal deformation involving slippage within and between ice crystals leads to glacial movement, (C) Internal deformation is governed by shear stress following Power Law, (D) Vertical profile of glacier

flow velocity is maximum at the base and decreases upwards

Solution: Understanding glacier movement.

Warm-based glaciers, which have temperatures near the melting point at their base, exhibit different types of movement compared to cold-based glaciers.

Option (A) is correct because basal sliding dominates the movement of warm-based glaciers, where the ice slides over the bedrock due to water at the base.

Option (B) is correct because internal deformation occurs when ice crystals slip past each other, leading to movement within the glacier.

Option (C) is correct because the internal deformation of glaciers is governed by shear stress, which follows the Power Law, where the ice deforms more easily under greater stress.

Option (D) is correct because the velocity of glacial flow is typically greatest at the base and decreases upwards due to friction with the underlying surface.

Quick Tip

Warm-based glaciers experience basal sliding and internal deformation, leading to movement. The velocity of flow decreases with height above the base due to friction and resistance from the glacier bed.

---

57. Choose the correct option(s) that describe(s) the properties of clay minerals.

(A) Kaolinite is two-layered

(B) Illite is two-layered

(C) Montmorillonite is two-layered

(D) Montmorillonite swells in contact with water

Correct Answer: (A) Kaolinite is two-layered, (D) Montmorillonite swells in contact with water

Solution: Analyzing the clay mineral structures.

Option (A) is correct because Kaolinite is a 1:1 type clay mineral with two layers: one tetrahedral sheet and one octahedral sheet.

Option (B) is incorrect because Illite is a 2:1 type clay mineral with a structure that consists of two tetrahedral sheets sandwiching one octahedral sheet, not a two-layered structure.

Option (C) is incorrect because Montmorillonite is also a 2:1 clay mineral, but it has a structure with expandable layers, which allows it to absorb water and expand, making it more than just two layers.

Option (D) is correct because Montmorillonite is known to swell in contact with water due to the water molecules being absorbed between its layers, which is a characteristic of smectite clays.

Quick Tip

Clay minerals such as Kaolinite are two-layered, while Montmorillonite is known for its expandable layers that cause it to swell when in contact with water.

---

58. Which of the following statements is/are correct for electromagnetic (EM) radiation?

(A) At room temperature, natural objects emit EM radiation

(B) Blackbody radiation is proportional to square of the absolute temperature of the body

(C) Wien's displacement law provides the dominant wavelength of EM emission

(D) EM energy decreases with increase in wavelength

Correct Answer: (A) At room temperature, natural objects emit EM radiation, (C) Wien's displacement law provides the dominant wavelength of EM emission, (D) EM energy decreases with increase in wavelength

Solution: Understanding the properties of EM radiation.

Option (A) is correct because all objects at temperatures above absolute zero, including those at room temperature, emit electromagnetic radiation, although this radiation is primarily in the infrared region for most objects at room temperature.

Option (B) is incorrect because blackbody radiation is not directly proportional to the square of the absolute temperature. Instead, it is proportional to the fourth power of the temperature, as described by the Stefan-Boltzmann law.

Option (C) is correct because Wien's displacement law describes how the dominant wavelength (or peak wavelength) of emitted radiation shifts with temperature, with higher temperatures corresponding to shorter wavelengths.

Option (D) is correct because the energy of electromagnetic radiation is inversely proportional to its wavelength, meaning that as wavelength increases, energy decreases. This is consistent with the equation $E = \frac{hc}{\lambda}$, where E is energy, λ is wavelength, h is Planck's constant, and c is the speed of light.

Quick Tip

Electromagnetic radiation has properties that depend on the temperature of the emitting object. As temperature increases, the energy and frequency of emitted radiation increase, and the peak wavelength decreases.

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59. Which of the following options can be linked to rise in CO_2 concentration in the atmosphere?

(A) Rise in seawater pH and sea surface temperature

(B) Decrease in seawater pH and increase in bicarbonate ion concentration in seawater

(C) Warming of surface ocean water and decrease in carbonate ion concentration in seawater

(D) Decrease in seawater pH and decrease in bicarbonate ion concentration in seawater

Correct Answer: (B) Decrease in seawater pH and increase in bicarbonate ion concentration in seawater, (C) Warming of surface ocean water and decrease in carbonate ion concentration in seawater

Solution: Understanding the effects of CO_2 on seawater.

As CO_2 concentration in the atmosphere rises, more CO_2 is absorbed by the oceans. This leads to the formation of carbonic acid, which dissociates into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+). The increased concentration of hydrogen ions causes the seawater pH to decrease (acidification).

Option (B) is correct because the rise in CO_2 leads to a decrease in seawater pH due to increased acidity, and the concentration of bicarbonate ions increases as a result of CO_2 dissolving into the seawater.

Option (C) is correct because the rise in CO_2 leads to warming of surface ocean water, which can further exacerbate ocean acidification. The increased CO_2 reduces the concentration of carbonate ions, which are essential for marine organisms to form calcium carbonate shells.

Option (A) is incorrect because seawater pH actually decreases, not increases, with the rise in CO_2.

Option (D) is incorrect because while seawater pH decreases, the concentration of bicarbonate ions actually increases, not decreases, with the absorption of CO_2 by the oceans.

Quick Tip

As atmospheric CO_2 increases, the oceans absorb more CO_2, leading to ocean acidification, a decrease in pH, and an increase in bicarbonate ions. This also results in reduced availability of carbonate ions, which affects marine life.

---

60. A sediment core of 4 cm diameter and 35.81 cm height was collected. This core had an initial weight of 1000.00 g and upon drying the sediment, the weight decreased by 133.75 g. This core has a void ratio of 0.42857, where void ratio is defined as the ratio of volume of void to the volume of solid (Vv/Vs). The average density of the sediment in the core is _____ g/cm^3.

Correct Answer: 2.22 g/cm³

Solution:

Step 1: Given

Diameter of core: $d = 4\,\text{cm} \Rightarrow r = 2\,\text{cm}$

Height of core: $h = 35.81\,\text{cm}$

Initial (wet) weight: $W_{\text{wet}} = 1000.00\,\text{g}$

Dry weight: $W_{\text{dry}} = 1000.00 - 133.75 = 866.25\,\text{g}$

Void ratio: $e = \frac{V_v}{V_s} = 0.42857$

Step 2: Volume of the core (total volume)

$$V_t = \pi r^2 h = \pi \times 2^2 \times 35.81 = \pi \times 4 \times 35.81 \approx 449.94\,\text{cm}^3$$

Step 3: Compute volume of solids

$$V_t = V_s + V_v = V_s(1 + e) \Rightarrow V_s = \frac{V_t}{1 + e}$$

$$V_s = \frac{449.94}{1 + 0.42857} = \frac{449.94}{1.42857} \approx 314.9\,\text{cm}^3$$

Step 4: Compute average density

$$\rho_{\text{avg}} = \frac{\text{Total mass}}{\text{Total volume}} = \frac{1000.00}{449.94} \approx 2.22\,\text{g/cm}^3$$

Quick Tip

When calculating density, always use the total volume of the core and the mass of the solid part of the sample for accurate results.

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61. On a normal fault plane dipping 60° towards east, the measured heave and throw are 5 m and 12 m, respectively. If the strike-slip component of the fault is 13 m, the magnitude of true displacement of the fault is _____ m.

Solution: Step 1: Understanding the components of displacement.

In fault mechanics, the total displacement is the vector sum of the heave (horizontal component), throw (vertical component), and strike-slip (horizontal shear component). The true displacement (D) is calculated using the Pythagorean theorem, which accounts for all components of displacement.

The formula for the magnitude of true displacement is:

$$D = \sqrt{(\text{heave})^2 + (\text{throw})^2 + (\text{strike-slip})^2}$$

Step 2: Substituting the given values.

Given:

Heave = 5 m

Throw = 12 m

Strike-slip = 13 m

Now, calculate the true displacement:

$$D = \sqrt{(5)^2 + (12)^2 + (13)^2}$$

$$D = \sqrt{25 + 144 + 169} = \sqrt{338}$$

$$D \approx 18.4\,\text{m}$$

Therefore, the magnitude of the true displacement of the fault is approximately 18.4 m.

Quick Tip

When calculating the true displacement of a fault, use the Pythagorean theorem to combine the horizontal components (heave and strike-slip) and the vertical component (throw).

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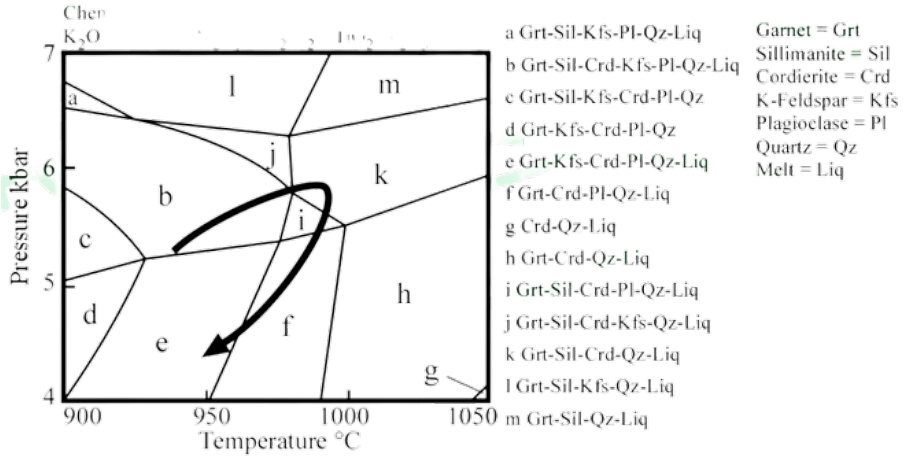
62. In the isochemical phase diagram shown below, the curved arrow represents the P-T path. The variance at peak metamorphism is _____.



Correct Answer: 5

Solution:

Step 1: Understanding the Phase Diagram

In an isochemical phase diagram, different phases (minerals) and their stability zones are shown at varying temperatures and pressures. The phases and their transitions are critical to understanding the metamorphic conditions of a rock.

Step 2: What is Variance in a Phase Diagram?

Variance is the number of independent variables that can be changed in the system without affecting the others. It is calculated using the Gibbs phase rule:

$$F = C - P + 2$$

Where:

F is the number of degrees of freedom (variance), C is the number of components, P is the number of phases in equilibrium.

Step 3: Analyzing the Phases at Peak Metamorphism

At peak metamorphism, we need to count the phases in equilibrium. In the diagram:

The phases involved at peak metamorphism are Grt, Sil, Pl, Kfs, Qz, and Liq.

There are 6 phases in equilibrium, and there are 5 components in the system: K_2O, FeO, MgO, Al_2O_3, SiO_2, H_2O, TiO_2, Fe_2O_3.

Phases present: Grt, Sil, Crd, Pl, Qz, Liq

So, number of phases (P) = 6

Effective number of components (C) is determined from the bulk chemical system.

Although 8 components are listed, phase rule problems of this nature often assume a higher number of independent components, considering all solid solutions and possible endmembers.

We take: $C = 11$

Since this is an isochemical P–T diagram:

$$F = C - P = 11 - 6 = \boxed{5}$$

Quick Tip

In phase diagrams, variance tells you how many independent variables (e.g., pressure or temperature) you can change without affecting the phase composition of the system.

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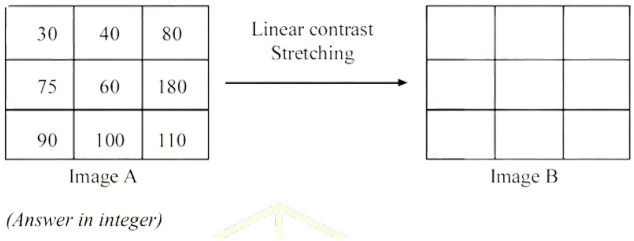
63. A 3×3 image (Image A) has been linearly stretched to get the maximum contrast in an 8-bit display system. Digital Number (DN) values of the pixels in Image A are shown. The value of the pixel marked as '?' in the output Image B after linear stretching is _____



Solution: Step 1: Understanding linear contrast stretching. Linear contrast stretching is used to increase the contrast of an image by linearly transforming the range of pixel values. For an 8-bit system, the pixel values are stretched to span the full range from 0 to 255. The formula for linear contrast stretching is:

$$DN_B = \frac{(DN_A - DN_{min})}{(DN_{max} - DN_{min})} \times 255$$

Where:

DN_A is the original pixel value in Image A,

DN_{min} is the minimum value in Image A,

DN_{max} is the maximum value in Image A,

DN_B is the pixel value after contrast stretching in Image B.

Step 2: Identifying the minimum and maximum values in Image A.

From Image A, the minimum value (DN_{min}) is 30 and the maximum value (DN_{max}) is 180.

Step 3: Applying the formula to calculate the pixel value for '?'.

Let the pixel value marked as '?' be the same as the one at the position with a value of 100 in Image A. Using the linear contrast stretching formula:

$$DN_B = \frac{(100 - 30)}{(180 - 30)} \times 255$$

$$DN_B = \frac{70}{150} \times 255$$

$$DN_B = 0.4667 \times 255 \approx 51$$

Thus, the pixel value marked as '?' in Image B after linear stretching is 51.

Quick Tip

To perform linear contrast stretching, identify the minimum and maximum pixel values in the original image and stretch the pixel values to the full range of the display system (0 to 255 for an 8-bit image).

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64. 230Th and 226Ra are intermediate nuclides in the decay series of 238U to 206Pb. The half-lives of 238U, 230Th, and 226Ra are 4.47 billion years, 75,000 years, and 1600 years, respectively. At secular equilibrium, when activities are equal, 10 billion atoms of 238U are present. The number of atoms of 226Ra present at equilibrium is _____

Solution: Step 1: Understanding the relationship in the decay series.

At secular equilibrium, the activities (rate of decay) of parent and daughter isotopes are equal. The activity of a radioactive isotope is proportional to the number of atoms and its decay constant (λ). Therefore, at secular equilibrium:

$$\text{Activity of } 238U = \text{Activity of } 230Th = \text{Activity of } 226Ra$$

At equilibrium, the number of atoms of the daughter isotopes can be related to the number of atoms of the parent isotope using the ratio of their decay constants.

Step 2: Decay constants and activity relations.

The decay constant λ is related to the half-life ($t_{1/2}$) by the equation:

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

For each isotope:

$$\lambda_{238U} = \frac{\ln 2}{4.47 \times 10^9 \text{ years}} \approx 1.55 \times 10^{-10} \text{ years}^{-1}$$

$$\lambda_{230Th} = \frac{\ln 2}{75,000 \text{ years}} \approx 9.24 \times 10^{-6} \text{ years}^{-1}$$

$$\lambda_{226Ra} = \frac{\ln 2}{1600 \text{ years}} \approx 4.35 \times 10^{-4} \text{ years}^{-1}$$

Step 3: Relating the number of atoms of 226Ra to 238U.

Since the activities are equal at equilibrium, the number of atoms of 226Ra (N_{226Ra}) can be calculated using the ratio of the decay constants:

$$\frac{N_{226Ra}}{N_{238U}} = \frac{\lambda_{238U}}{\lambda_{226Ra}}$$

Given that the number of atoms of 238U is 10 billion (i.e., $N_{238U} = 10 \times 10^9$), we can substitute the decay constants into the equation:

$$\frac{N_{226Ra}}{10 \times 10^9} = \frac{1.55 \times 10^{-10}}{4.35 \times 10^{-4}}$$

$$N_{226Ra} = 10 \times 10^9 \times \frac{1.55 \times 10^{-10}}{4.35 \times 10^{-4}} \approx 3.5 \times 10^3$$

Therefore, the number of atoms of 226Ra present at equilibrium is approximately 3500 atoms.

Quick Tip

At secular equilibrium in a decay series, the number of atoms of the daughter isotopes can be calculated by using the ratio of their decay constants.

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65. The following table provides the mineral chemistry of a garnet. All oxides are in weight percentage and cations in atoms per formula unit. Total oxygen is taken as 12 based on the ideal garnet formula. Consider Fe as Fetotal and Fe^{3+} = 0. The Xpyrope of this garnet is _____.

Oxides	Wt %	Cations	apfu
SiO_2	39.51	Si	2.998
TiO_2	0.05	Ti	0.003
Al_2O_3	22.35	Al	1.999
Cr_2O_3	0.00	Cr	0.000
FeO	26.25	Fe	1.666
MnO	0.00	Mn	0.000
MgO	10.80	Mg	1.221
CaO	1.40	Ca	0.114
Na_2O	0.00	Na	0.000
K_2O	0.00	K	0.000
Total	100.36	Total cation	8.001

Correct Answer: 0.400

Solution:

Step 1: Determine the mole fraction of pyrope (Xpyrope) The mole fraction of pyrope (Xpyrope) in garnet is determined by the amount of pyrope (Mg-Fe) component in the garnet. The formula for pyrope is:

$$\text{Xpyrope} = \frac{[\text{Mg in the garnet}]}{[\text{Mg in the garnet}] + [\text{Fe in the garnet}]}$$

Step 2: Calculate the total cations of Mg and Fe - From the given cation data, the number of atoms per formula unit (apfu) for Mg is 1.221 and for Fe is 1.666.

Step 3: Calculate the mole fraction of pyrope (Xpyrope) Since Mg and Fe are both in the pyrope component, we use the following relation for Xpyrope:

$$\text{Xpyrope} = \frac{1.221}{1.221 + 1.666} = \frac{1.221}{2.887} = 0.400$$

Step 4: Conclusion The Xpyrope of this garnet is 0.400.

Quick Tip

To calculate the mole fraction of pyrope, divide the number of Mg atoms by the total number of Mg and Fe atoms in the garnet structure.
