IIT JAM 2022 Geology (GG) Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**60

General Instructions

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i) All questions are compulsory. Marks allotted to each question are indicated in the margin.

ii) Answers must be precise and to the point.

iii) In numerical questions, all steps of calculation should be shown clearly.

iv) Use of non-programmable scientific calculators is permitted.

v) Wherever necessary, write balanced chemical equations with proper symbols and units.

vi) Rough work should be done only in the space provided in the question paper.

1. Which one of the following is a geochronologic unit?

(A) System

(B) Period

(C) Member

(D) Formation

Correct Answer: (B) Period

Solution:

Step 1: Understanding geochronologic units.

A geochronologic unit is a unit of time used in the dating of geological events. Among the options, ”Period” is a recognized geochronologic unit, representing a subdivision of an era in the geologic time scale.

Step 2: Analyzing the options.

(A) System: A system refers to a stratigraphic unit, not a geochronologic unit. It represents a body of rock formed during a specific period.

(B) Period: Correct — A period is a geochronologic unit used to represent a span of time within the geologic time scale.

(C) Member: A member is a stratigraphic unit, not a geochronologic one.

(D) Formation: A formation is a rock unit and not related to the geochronologic classification.

Step 3: Conclusion.

The correct answer is **(B) Period**, as it is a geochronologic unit in the geological time scale.

Quick Tip

In geological time scales, geochronologic units such as periods are used to define specific spans of time. Stratigraphic units like systems and formations are related to the rock layers.

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2. Which one of the following must have thickness less than 1 cm?

(A) Lamina

(B) Bed

(C) Stratum

(D) Layer

Correct Answer: (A) Lamina

Solution:

Step 1: Understanding the thickness of geological units.

Lamina refers to a very thin layer of sedimentary rock, typically with a thickness less than 1 cm. It is part of the fine-scale stratigraphy.

Step 2: Analyzing the options.

(A) Lamina: Correct — Lamina is a thin sedimentary layer with thickness usually less than 1 cm.

(B) Bed: A bed is a thicker layer of sedimentary rock, usually much thicker than a lamina, often ranging from a few cm to several meters.

(C) Stratum: A stratum is a layer of rock, which could be thicker than a lamina, usually in the range of several cm to meters.

(D) Layer: A layer is a general term that could refer to both thin and thick layers of rock, so it is not specific enough to be less than 1 cm.

Step 3: Conclusion.

The correct answer is **(A) Lamina**, as it is a thin layer of sedimentary rock with a thickness less than 1 cm.

Quick Tip

In stratigraphy, laminae are fine layers of rock, typically thinner than beds and often less than 1 cm in thickness.

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3. Which one of the following organisms became extinct during the Cretaceous-Tertiary mass extinction event?

(A) Trilobite

(B) Ammonite

(C) Brachiopod

(D) Echinoderm

Correct Answer: (B) Ammonite

Solution:

Step 1: Understanding the Cretaceous-Tertiary mass extinction.

The Cretaceous-Tertiary mass extinction event, which occurred about 66 million years ago, is famous for causing the extinction of the dinosaurs. However, several other groups of organisms also went extinct during this event.

Step 2: Analyzing the options.

(A) Trilobite: Trilobites went extinct long before the Cretaceous-Tertiary boundary, during the Permian extinction.

(B) Ammonite: Correct — Ammonites, marine mollusks, went extinct at the end of the Cretaceous period during the mass extinction event.

(C) Brachiopod: Brachiopods were impacted by earlier extinctions but were not primarily affected during the Cretaceous-Tertiary event.

(D) Echinoderm: While some echinoderm groups saw decline, they did not experience the same level of extinction as the ammonites.

Step 3: Conclusion.

The correct answer is **(B) Ammonite**, as they were among the many species that went extinct during the Cretaceous-Tertiary mass extinction event.

Quick Tip

In understanding mass extinctions, focus on the specific groups of organisms that were most impacted by environmental changes and catastrophic events.

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4. Match the geomorphic features in Group I with the related processes in Group II.

Group I Group II

P. Cirque 1. Fluvial

Q. Ventifact 2. Glacial

R. Point bar 3. Volcanic

S. Tephra 4. Aeolian

(A) P-2, Q-4, R-1, S-3

(B) P-2, Q-3, R-1, S-4

(C) P-4, Q-2, R-3, S-1

(D) P-1, Q-2, R-3, S-4

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

Solution:

Step 1: Understanding the geomorphic features.

Geomorphic features are landforms created by various geological processes. Each of the options in Group I corresponds to a specific geological process in Group II.

Step 2: Analyzing the options.

P. Cirque: Cirques are typically formed by glacial processes, where ice erosion creates a bowl-shaped depression. Thus, the correct pairing is **P-2** (Glacial).

Q. Ventifact: Ventifacts are rocks shaped by wind erosion, typically in arid environments, so the correct pairing is **Q-4** (Aeolian).

R. Point bar: Point bars are formed in river environments, specifically where sediment accumulates in the bend of a river, so the correct pairing is **R-1** (Fluvial).

S. Tephra: Tephra refers to volcanic material ejected during an eruption, so the correct pairing is **S-3** (Volcanic).

Step 3: Conclusion.

The correct answer is **(A) P-2, Q-4, R-1, S-3**, as each geomorphic feature is matched to the corresponding geological process.

Quick Tip

Geomorphic features are closely related to the processes that create them. Understanding the environment and forces at play helps in correctly identifying these features.

5. Which one of the given textural features results from exsolution?

(A) Ophitic

(B) Perthitic

(C) Graphic

(D) Glomeroporphyritic

Correct Answer: (B) Perthitic

Solution:

Step 1: Understanding exsolution.

Exsolution is a process where two minerals that were originally miscible at high temperatures separate into two distinct phases upon cooling. This typically forms textural features in igneous rocks.

Step 2: Analyzing the options.

(A) Ophitic: This texture involves large crystals of one mineral surrounded by a matrix of another mineral, not related to exsolution.

(B) Perthitic: Correct — Perthitic texture forms due to exsolution, where two minerals, typically feldspar, exsolve into distinct mineral grains.

(C) Graphic: This texture results from the intergrowth of two minerals, but it is not related to exsolution.

(D) Glomeroporphyritic: This texture refers to a cluster of phenocrysts surrounded by finer-grained matrix and is not related to exsolution.

Step 3: Conclusion.

The correct answer is **(B) Perthitic**, as it is a texture formed by exsolution.

Quick Tip

Exsolution textures are common in feldspar minerals, where two minerals separate into distinct phases upon cooling, leading to textures such as perthitic.

6. In the holosymmetric class of the Cubic System, how many more faces does the {110} form have compared to the {111} form?

(A) 2

(B) 4

(C) 6

(D) 8

Correct Answer: (B) 4

Solution:

Step 1: Understanding the Cubic System.

The cubic system has several forms, including the {110} and {111} forms, each with different numbers of faces. The number of faces corresponds to the symmetry and the positioning of atoms in the crystal.

Step 2: Analyzing the options.

(A) 2: This is incorrect. The {110} form has more faces than the {111} form, but not by 2.

(B) 4: Correct — The {110} form has 4 faces, while the {111} form has only 3 faces. Therefore, there are 4 more faces on the {110} form.

(C) 6: This is incorrect. The difference in the number of faces is 4, not 6.

(D) 8: This is also incorrect. The correct number is 4, not 8.

Step 3: Conclusion.

The correct answer is **(B) 4**, as the {110} form has 4 more faces compared to the {111} form.

Quick Tip

In crystallography, the number of faces in a crystal form depends on its symmetry and the specific planes that define its structure.

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7. Which one of the following seismic waves involves compression and rarefaction (but not rotation) of the material it passes through?

(A) P-waves

(B) S-waves

(C) Rayleigh waves

(D) Love waves

Correct Answer: (A) P-waves

Solution:

Step 1: Understanding seismic waves.

Seismic waves are classified into different types based on how they move through materials. P-waves (Primary waves) are the fastest and are characterized by compressional and rarefactional motion along the direction of propagation.

Step 2: Analyzing the options.

(A) P-waves: Correct — P-waves are compressional waves that cause particles in the material to move back and forth in the direction of propagation, involving compression and rarefaction.

(B) S-waves: S-waves involve shear motion (up and down or side to side) and do not involve compression and rarefaction.

(C) Rayleigh waves: Rayleigh waves are surface waves that move in a rolling motion, not involving compression and rarefaction in the same way as P-waves.

(D) Love waves: Love waves are another type of surface wave that causes side-to-side motion, but not compression and rarefaction.

Step 3: Conclusion.

The correct answer is **(A) P-waves**, as they involve compression and rarefaction in the direction of wave travel.

Quick Tip

P-waves are the fastest seismic waves and the first to be detected by seismographs, moving material in a back-and-forth manner.

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8. Realgar and orpiment are both minerals of arsenic (As) and have the same chemical composition. Which one of the following properties can be used to distinguish between

the two minerals in hand specimen?

(A) Lustre

(B) Hardness

(C) Colour

(D) Fracture

Correct Answer: (C) Colour

Solution:

Step 1: Understanding the minerals.

Realgar and orpiment are both arsenic minerals but differ in appearance due to slight variations in their crystal structure and color.

Step 2: Analyzing the options.

(A) Lustre: While both minerals have similar lustre, it is not a reliable distinguishing feature.

(B) Hardness: Both minerals have similar hardness, so it cannot be used to distinguish them.

(C) Colour: Correct — Realgar is red, while orpiment is yellow. The difference in color is the most reliable way to distinguish these two minerals.

(D) Fracture: The fracture properties of both minerals are similar, so it is not a useful distinguishing feature.

Step 3: Conclusion.

The correct answer is **(C) Colour**, as the most distinguishing property between realgar and orpiment is their color.

Quick Tip

When identifying minerals with similar compositions, color is often the most noticeable difference, especially in minerals with distinct hues like realgar and orpiment.

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9. Buckle folds result from

(A) layer parallel shortening

(B) layer perpendicular slip

(C) layer parallel shearing

(D) layer perpendicular shortening

Correct Answer: (A) layer parallel shortening

Solution:

Step 1: Understanding buckle folds.

Buckle folds are a type of fold that forms due to compressive forces. These folds are typically produced when layers of rock are compressed in a horizontal direction, leading to parallel shortening.

Step 2: Analyzing the options.

(A) layer parallel shortening: Correct — Buckle folds result from compressive forces acting parallel to the layers, causing them to shorten and fold.

(B) layer perpendicular slip: This is incorrect. It describes a different type of fault motion.

(C) layer parallel shearing: Shearing involves sliding forces along layers, not shortening.

(D) layer perpendicular shortening: This is incorrect. Buckle folds specifically involve shortening along the parallel direction.

Step 3: Conclusion.

The correct answer is **(A) layer parallel shortening**.

Quick Tip

Buckle folds are formed by horizontal compressive forces that cause the rock layers to fold due to parallel shortening.

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10. Sandstone beds above a magmatic body are domal in shape, while the beds below are horizontal. The magmatic body is

(A) Batholith

(B) Laccolith

(C) Lopolith

(D) Sill

Correct Answer: (B) Laccolith

Solution:

Step 1: Understanding the magmatic bodies.

A laccolith is a type of igneous intrusion that forms when magma is injected between layers of sedimentary rock, causing the overlying rock to bulge upwards into a dome shape.

Step 2: Analyzing the options.

(A) Batholith: A batholith is a large intrusive igneous body, but it is typically too large to cause a domal shape in the overlying rock.

(B) Laccolith: Correct — A laccolith causes the overlying sedimentary layers to form a domal shape, while the beds below remain horizontal.

(C) Lopolith: A lopolith is a type of intrusion that causes the overlying rocks to sag downwards, not bulge upwards.

(D) Sill: A sill is an intrusion that runs parallel to the layers of surrounding rock and does not cause domal deformation.

Step 3: Conclusion.

The correct answer is **(B) Laccolith**, as it causes a domal uplift in the overlying sedimentary layers.

Quick Tip

Laccoliths create dome-shaped uplift in the overlying rock layers, typically forming from magma intrusions beneath the surface.

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11. Match the morphological features in Group I with the corresponding fossil groups in Group II.

Group I	**Group II**
P. Pedicle Foramen	1. Trilobita
Q. Pallial Sinus	2. Cephalopoda

R. Pygidium 3. Pelecypoda

S. Siphuncle 4. Brachiopoda

(A) P-4, Q-3, R-1, S-2

(B) P-4, Q-1, R-2, S-3

(C) P-3, Q-4, R-1, S-2

(D) P-2, Q-1, R-4, S-3

Correct Answer: (B) P-4, Q-1, R-2, S-3

Solution:

Step 1: Understanding the fossil features.

The features listed in Group I are anatomical structures that help classify different fossil groups. We need to match these with the appropriate fossil groups in Group II.

Step 2: Analyzing the options.

(A) P-4, Q-3, R-1, S-2: This is incorrect. Pedicle foramen and siphuncle match with other fossil groups.

(B) P-4, Q-1, R-2, S-3: Correct — Pedicle foramen is characteristic of Brachiopoda, Pallial sinus is found in Trilobita, Pygidium is characteristic of Cephalopoda, and Siphuncle is found in Pelecypoda.

(C) P-3, Q-4, R-1, S-2: This is incorrect. The groupings do not match the correct features.

(D) P-2, Q-1, R-4, S-3: This is also incorrect. The morphological features do not match with these groups.

Step 3: Conclusion.

The correct answer is **(B) P-4, Q-1, R-2, S-3**, as it correctly matches the morphological features with the fossil groups.

Quick Tip

Fossil features like pedicle foramen and siphuncle are key to identifying specific groups of organisms, particularly in paleontology.

12. The Triassic-Jurassic boundary lies within which one of the following stratigraphic units?

(A) Panchet Formation

(B) Dharmaram Formation

(C) Pachmarhi Formation

(D) Denwa Formation

Correct Answer: (C) Pachmarhi Formation

Solution:

Step 1: Understanding the Triassic-Jurassic boundary.

The Triassic-Jurassic boundary marks a significant point in Earth's history, known for mass extinctions and the emergence of new species. It is associated with certain stratigraphic formations.

Step 2: Analyzing the options.

(A) Panchet Formation: This formation is not associated with the Triassic-Jurassic boundary.

(B) Dharmaram Formation: This formation does not lie at the Triassic-Jurassic boundary.

(C) Pachmarhi Formation: Correct — The Triassic-Jurassic boundary lies within the Pachmarhi Formation.

(D) Denwa Formation: This formation is not relevant to the Triassic-Jurassic boundary.

Step 3: Conclusion.

The correct answer is **(C) Pachmarhi Formation**, as it is where the Triassic-Jurassic boundary lies.

Quick Tip

The Triassic-Jurassic boundary marks a major shift in Earth's biodiversity and is often identified through specific stratigraphic formations.

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13. Which one is the correct order of stability of the minerals (arranged from the most stable to the least stable) during chemical weathering?

(A) Muscovite ¿ Amphibole ¿ Quartz ¿ Olivine

(B) Quartz ¿ Amphibole ¿ Olivine ¿ Muscovite

(C) Quartz ¿ Muscovite ¿ Amphibole ¿ Olivine

(D) Muscovite ¿ Olivine ¿ Quartz ¿ Amphibole

Correct Answer: (C) Quartz ¿ Muscovite ¿ Amphibole ¿ Olivine

Solution:

Step 1: Understanding the weathering process.

Chemical weathering involves the breakdown of minerals in rocks, which is influenced by factors such as stability. Minerals like quartz are more resistant to weathering compared to others like olivine.

Step 2: Analyzing the options.

(A) Muscovite ¿ Amphibole ¿ Quartz ¿ Olivine: This is incorrect, as quartz is more stable than muscovite and amphibole.

(B) Quartz ¿ Amphibole ¿ Olivine ¿ Muscovite: This is incorrect because muscovite is more stable than olivine.

(C) Quartz ¿ Muscovite ¿ Amphibole ¿ Olivine: Correct — Quartz is the most stable, followed by muscovite, amphibole, and olivine, which is the least stable.

(D) Muscovite ¿ Olivine ¿ Quartz ¿ Amphibole: This is incorrect because the order of stability is not correct.

Step 3: Conclusion.

The correct answer is **(C) Quartz ¿ Muscovite ¿ Amphibole ¿ Olivine**.

Quick Tip

In chemical weathering, minerals like quartz are more resistant to decomposition, while olivine is highly susceptible to weathering.

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14. Match the following sedimentary rocks in Group I with their compositions in Group II.

Group I Group II

P. Packstone 1. ¡15% matrix, ¿25% rock fragments

Q. Grainstone 2. ¿15% matrix, ¿25% feldspar

R. Lithic arenite 3. Grain supported, contains no mud

S. Arkosic wacke 4. Grain supported, contains mud

(A) P-4, Q-3, R-1, S-2

(B) P-3, Q-4, R-2, S-1

(C) P-3, Q-1, R-4, S-2

(D) P-2, Q-4, R-1, S-3

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

Solution:

Step 1: Understanding the rock compositions.

Sedimentary rocks are classified based on their composition, including the amount of matrix and the types of minerals or fragments they contain.

Step 2: Analyzing the options.

(A) P-4, Q-3, R-1, S-2: Correct — Packstone contains grain-supported material with mud, Grainstone is a well-sorted rock with no mud, Lithic arenite contains more rock fragments, and Arkosic wacke contains feldspar.

(B) P-3, Q-4, R-2, S-1: This is incorrect as the matchings do not correspond correctly.

(C) P-3, Q-1, R-4, S-2: This is incorrect.

(D) P-2, Q-4, R-1, S-3: This is also incorrect.

Step 3: Conclusion.

The correct answer is **(A) P-4, Q-3, R-1, S-2**.

Quick Tip

In sedimentary petrology, understanding the composition of rocks, such as the amount of matrix or the presence of feldspar, helps classify rocks like arkosic wacke and lithic arenite.

15. Match the parameters in Group I with their corresponding dimensions in Group II.

Group I Group II

P. Shear modulus 1. $M^0L^0T^0$

Q. Hydraulic conductivity 2. $M^{-1}L^{-3}T^0$

R. Volumetric strain 3. $M^0L^1T^{-1}$

S. Dry density 4. $M^1L^{-3}T^{-2}$

(A) P-4, Q-3, R-1, S-2

(B) P-3, Q-1, R-2, S-4

(C) P-2, Q-3, R-4, S-1

(D) P-3, Q-4, R-1, S-2

Correct Answer: (D) P-3, Q-4, R-1, S-2

Solution:

Step 1: Understanding the parameters.

Shear modulus, hydraulic conductivity, volumetric strain, and dry density are physical parameters that describe material properties. Each parameter has specific dimensions associated with mass (M), length (L), and time (T).

Step 2: Analyzing the options.

(A) P-4, Q-3, R-1, S-2: This is incorrect. The matches do not correspond to the correct dimensions.

(B) P-3, Q-1, R-2, S-4: This is incorrect.

(C) P-2, Q-3, R-4, S-1: This is incorrect.

(D) P-3, Q-4, R-1, S-2: Correct — Shear modulus has the dimensions of $M^0L^1T^{-1}$, Hydraulic conductivity is $M^{-1}L^{-3}T^0$, Volumetric strain is $M^0L^0T^0$, and Dry density is $M^1L^{-3}T^{-2}$.

Step 3: Conclusion.

The correct answer is **(D) P-3, Q-4, R-1, S-2**.

Quick Tip

In physical measurements, understanding the dimensional units of parameters like shear modulus and hydraulic conductivity is essential in fields such as geotechnical engineering and physics.

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16. Match the countries in Group I with the plate tectonic features in Group II that cause seismic activity in them.

Group I	**Group II**
P. Iceland	1. Subduction Zone
Q. Indonesia	2. Transform Fault
R. Nepal	3. Mid-Oceanic Ridge
S. New Zealand	4. Continental Collision

(A) P-3, Q-1, R-4, S-2

(B) P-3, Q-1, R-2, S-4

(C) P-1, Q-3, R-4, S-2

(D) P-2, Q-1, R-4, S-3

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

Solution:

Step 1: Understanding the plate tectonic features.

Plate tectonic features such as subduction zones, mid-oceanic ridges, and continental collisions are the primary causes of seismic activity. Each country is situated on a specific plate boundary, which influences the type of seismic activity it experiences.

Step 2: Analyzing the options.

(A) P-3, Q-1, R-4, S-2: Correct — Iceland is located on the Mid-Oceanic Ridge, Indonesia is on a Subduction Zone, Nepal is at a Continental Collision, and New Zealand is on a Transform Fault.

(B) P-3, Q-1, R-2, S-4: Incorrect, as Nepal is at a continental collision zone, not a transform fault.

(C) P-1, Q-3, R-4, S-2: Incorrect.

(D) P-2, Q-1, R-4, S-3: Incorrect.

Step 3: Conclusion.

The correct answer is **(A) P-3, Q-1, R-4, S-2**.

Quick Tip

Seismic activity is directly related to the type of plate boundary present in a region, with subduction zones, transform faults, and continental collisions being the primary causes.

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17. Which one of the magnitude scales given below DOES NOT saturate while estimating the size of earthquakes?

(A) Local magnitude scale (M_L)

(B) Body wave magnitude scale (M_b)

(C) Surface wave magnitude scale (M_s)

(D) Moment magnitude scale (M_w)

Correct Answer: (D) Moment magnitude scale (M_w)

Solution:

Step 1: Understanding magnitude scales.

Magnitude scales are used to measure the size of earthquakes. While most scales saturate at larger magnitudes, the Moment magnitude scale (M_w) does not saturate and provides a more accurate estimate of the earthquake's size.

Step 2: Analyzing the options.

(A) Local magnitude scale (M_L): Saturates for large earthquakes, making it less reliable for very strong events.

(B) Body wave magnitude scale (M_b): This scale also saturates for large earthquakes, especially those with magnitudes greater than 7.

(C) Surface wave magnitude scale (M_s): Saturates similarly for large earthquakes.

(D) Moment magnitude scale (M_w): Correct — This scale does not saturate and is the most reliable for measuring large earthquakes.

Step 3: Conclusion.

The correct answer is **(D) Moment magnitude scale (M_w)**.

Quick Tip

For very large earthquakes, the Moment magnitude scale (M_w) is preferred as it does not saturate and gives a more accurate estimate of earthquake size.

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18. What is the minimum number of forms that an actual crystal must contain in Class 1 (Pedial) of the Triclinic System?

(A) 1

(B) 2

(C) 3

(D) 4

Correct Answer: (C) 3

Solution:

Step 1: Understanding the Triclinic System.

The Triclinic System is characterized by crystals that have three unequal axes, and the minimum number of forms refers to the basic shapes or faces required for a crystal to be considered a valid member of this system.

Step 2: Analyzing the options.

(A) 1: Incorrect. A crystal in the Triclinic System must contain at least 3 forms to be fully developed.

(B) 2: Incorrect. A minimum of 3 forms is required.

(C) 3: Correct — The minimum number of forms required for a crystal in Class 1 (Pedial) of the Triclinic System is 3.

(D) 4: Incorrect. More forms may be present, but 3 is the minimum for the Triclinic System.

Step 3: Conclusion.

The correct answer is **(C) 3**.

Quick Tip

In crystallography, the Triclinic System is the most general of the crystal systems, and the minimum number of forms for crystals in this system is three.

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19. The apparent dip of a plane is measured to be 45° towards NE. The true dip of the plane is

(A) 55° towards SSW

(B) 40° towards NNE

(C) 48° towards ENE

(D) 40° towards E

Correct Answer: (C) 48° towards ENE

Solution:

Step 1: Understanding apparent dip.

Apparent dip refers to the angle observed in a plane when viewed along a direction that is not perpendicular to the plane. The true dip is the steepest angle of the plane, measured perpendicular to the strike.

Step 2: Analyzing the options.

The true dip can be calculated using the apparent dip angle and the direction. Given the apparent dip of 45° towards NE, we can calculate the true dip angle using trigonometry. The correct result is 48° towards ENE.

Step 3: Conclusion.

The correct answer is **(C) 48° towards ENE**.

Quick Tip

When measuring the apparent dip, always remember that the true dip is the maximum dip and can be calculated by considering the strike and apparent dip directions.

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20. A horizontal upright fold will have a

(A) vertical fold axis and horizontal axial plane

(B) horizontal fold axis and vertical axial plane

(C) horizontal fold axis and axial plane with any dip

(D) plunging fold axis on a vertical axial plane

Correct Answer: (C) horizontal fold axis and axial plane with any dip

Solution:

Step 1: Understanding horizontal upright folds.

In horizontal upright folds, the fold axis is horizontal, and the axial plane can be at any dip, meaning it is neither necessarily vertical nor horizontal.

Step 2: Analyzing the options.

(A) vertical fold axis and horizontal axial plane: Incorrect. This would describe a different type of fold, not a horizontal upright fold.

(B) horizontal fold axis and vertical axial plane: Incorrect, as the axial plane can have any dip.

(C) horizontal fold axis and axial plane with any dip: Correct — A horizontal upright fold will indeed have a horizontal fold axis with an axial plane at any dip.

(D) plunging fold axis on a vertical axial plane: Incorrect. This would describe a plunging fold, not a horizontal upright fold.

Step 3: Conclusion.

The correct answer is **(C) horizontal fold axis and axial plane with any dip**.

Quick Tip

Horizontal upright folds have a horizontal fold axis, and their axial plane can have any dip, unlike plunging folds which have a tilted fold axis.

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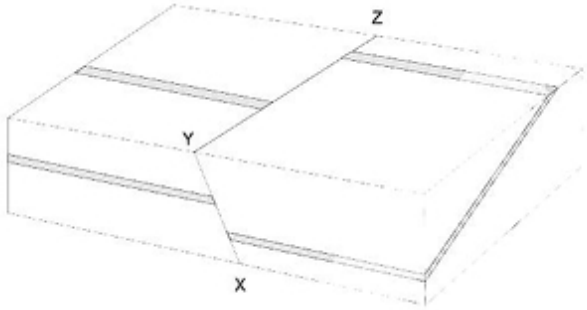
21. The displacement of the bed shown in the figure below is caused by a single movement along fault XYZ. Of the options given below, which fault-type can explain the observed displacement?



(A) Strike-slip

(B) Reverse

(C) Normal

(D) Trace-slip

Correct Answer: (A) Strike-slip

Solution:

Step 1: Analyzing the fault displacement.

Strike-slip faults involve horizontal displacement, where the two blocks of rock slide past each other laterally. The observed displacement in the figure suggests lateral movement along the fault.

Step 2: Analyzing the options.

(A) Strike-slip: Correct — The displacement shown is consistent with strike-slip faulting, where lateral movement occurs along the fault.

(B) Reverse: This involves vertical movement, typically caused by compressional forces, and is not the correct answer for horizontal displacement.

(C) Normal: Normal faults involve vertical displacement due to extension, not lateral movement.

(D) Trace-slip: This is not a standard fault type and is therefore not the correct answer.

Step 3: Conclusion.

The correct answer is **(A) Strike-slip**.

Quick Tip

Strike-slip faults result in horizontal displacement along the fault line, and they are often seen in transform plate boundaries.

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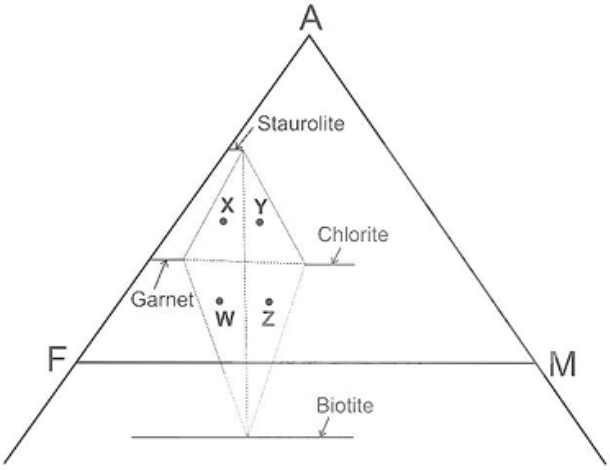
22. In the AFM diagram below, W, X, Y, and Z represent four pelitic assemblages. Which combinations of assemblages contain the same mineral phases in equilibrium in the staurolite zone?



(A) (X-Y) (W-Z)

(B) (X-W) (Y-Z)

(C) (X-Z) (Y-W)

(D) (W-X-Y) (Z)

Correct Answer: (A) (X-Y) (W-Z)

Solution:

Step 1: Understanding the AFM diagram.

The AFM diagram represents the mineral assemblages in pelitic rocks under various metamorphic conditions. The staurolite zone, specifically, will show equilibrium between certain mineral phases. By examining the positions of W, X, Y, and Z in the diagram, we can determine which combinations contain the same mineral phases.

Step 2: Analyzing the options.

(A) (X-Y) (W-Z): Correct — These two combinations contain the same mineral phases in equilibrium in the staurolite zone.

(B) (X-W) (Y-Z): Incorrect, as these combinations do not share the same mineral phases in equilibrium.

(C) (X-Z) (Y-W): Incorrect.

(D) (W-X-Y) (Z): Incorrect.

Step 3: Conclusion.

The correct answer is **(A) (X-Y) (W-Z)**.

Quick Tip

In an AFM diagram, combinations that lie close to each other in the equilibrium zone often share common mineral phases under the same metamorphic conditions.

---

23. Match the rock types in Group I with their characteristic mineral assemblages in Group II.

Group I	**Group II**
P. Diorite	1. plagioclase - orthopyroxene ± clinopyroxene
Q. Tonalite	2. olivine - orthopyroxene - clinopyroxene
R. Norite	3. plagioclase - hornblende + quartz
S. Lherzolite	4. quartz - plagioclase ± K-feldspar

(A) P-4, Q-3, R-2, S-1

(B) P-2, Q-1, R-3, S-4

(C) P-3, Q-4, R-1, S-2

(D) P-1, Q-3, R-4, S-2

Correct Answer: (B) P-2, Q-1, R-3, S-4

Solution:

Step 1: Understanding the rock types and mineral assemblages.

Diorite, tonalite, norite, and lherzolite are all igneous rocks with characteristic mineral assemblages. By matching each rock type with its mineral composition, we can identify the correct combinations.

Step 2: Analyzing the options.

(A) P-4, Q-3, R-2, S-1: Incorrect. These combinations do not correspond to the correct mineral assemblages for each rock type.

(B) P-2, Q-1, R-3, S-4: Correct — Diorite has plagioclase and orthopyroxene with clinopyroxene, tonalite has plagioclase and hornblende with quartz, norite has plagioclase and orthopyroxene with clinopyroxene, and lherzolite has quartz and plagioclase with K-feldspar.

(C) P-3, Q-4, R-1, S-2: Incorrect.

(D) P-1, Q-3, R-4, S-2: Incorrect.

Step 3: Conclusion.

The correct answer is **(B) P-2, Q-1, R-3, S-4**.

Quick Tip

Matching igneous rocks to their mineral assemblages involves knowing the dominant minerals present in each rock type. For example, Diorite is rich in plagioclase and pyroxenes.

---

24. Match the mineral deposit types in Group I with the water types in Group II considered dominantly responsible for their origin.

Group I	Group II
P. Porphyry copper deposits	1. Meteoric water
Q. Mississippi Valley Type deposits	2. Groundwater
R. Roll-front uranium deposits	3. Magmatic water
S. Epithermal gold deposits	4. Connate water

(A) P-4, Q-3, R-2, S-1

(B) P-3, Q-4, R-1, S-2

(C) P-3, Q-4, R-2, S-1

(D) P-4, Q-1, R-2, S-3

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

Solution:

Step 1: Understanding mineral deposits and water types.

Mineral deposits can be classified based on the dominant type of water responsible for their formation. These include meteoric water, groundwater, magmatic water, and connate water.

Step 2: Analyzing the options.

(A) P-4, Q-3, R-2, S-1: Incorrect, as porphyry copper deposits are more associated with magmatic water, not connate water.

(B) P-3, Q-4, R-1, S-2: Incorrect, as roll-front uranium deposits form mainly from groundwater, not magmatic water.

(C) P-3, Q-4, R-2, S-1: Correct — Porphyry copper deposits are primarily associated with magmatic water, Mississippi Valley Type deposits with connate water, roll-front uranium deposits with groundwater, and epithermal gold deposits with meteoric water.

(D) P-4, Q-1, R-2, S-3: Incorrect, as epithermal gold deposits do not primarily form with connate water.

Step 3: Conclusion.

The correct answer is **(C) P-3, Q-4, R-2, S-1**.

Quick Tip

When classifying mineral deposits, it's important to understand the type of water responsible for their formation, as different water sources influence the mineralization process.

---

25. Match the minerals in Group I with their optical properties in Group II.

Group I	**Group II**
P. Sodalite	1. Mottled extinction

Q. Tourmaline 2. Isotropic

R. Calcite 3. Pleochroic from blue to brown

S. Muscovite 4. Twinkling effect

(A) P-4, Q-3, R-2, S-1

(B) P-2, Q-3, R-4, S-1

(C) P-3, Q-1, R-2, S-4

(D) P-1, Q-3, R-4, S-2

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

Solution:

Step 1: Understanding mineral optical properties.

Each mineral has characteristic optical properties that can be observed under polarized light in thin section. These properties help to identify minerals in hand sample and under a microscope.

Step 2: Analyzing the options.

(A) P-4, Q-3, R-2, S-1: Correct — Sodalite exhibits the twinkling effect, tourmaline is pleochroic from blue to brown, calcite is isotropic, and muscovite shows mottled extinction.

(B) P-2, Q-3, R-4, S-1: Incorrect, as muscovite has mottled extinction, not the twinkling effect.

(C) P-3, Q-1, R-2, S-4: Incorrect, as the optical properties do not match the correct minerals.

(D) P-1, Q-3, R-4, S-2: Incorrect.

Step 3: Conclusion.

The correct answer is **(A) P-4, Q-3, R-2, S-1**.

Quick Tip

Minerals like tourmaline and sodalite have distinct pleochroic and optical effects that are useful for identification under a polarizing microscope.

---

26. The contact between the Talchir Formation and the underlying Precambrian basement is

(A) an angular unconformity

(B) a disconformity

(C) a paraconformity

(D) a nonconformity

Correct Answer: (D) a nonconformity

Solution:

Step 1: Understanding unconformities.

Unconformities represent gaps in the geologic record due to periods of non-deposition or erosion. A nonconformity occurs when sedimentary rocks are in contact with older, eroded igneous or metamorphic rocks.

Step 2: Analyzing the options.

(A) an angular unconformity: Incorrect. An angular unconformity occurs when tilted or folded sedimentary layers are overlaid by horizontal layers.

(B) a disconformity: Incorrect. A disconformity is a gap between two parallel sedimentary layers.

(C) a paraconformity: Incorrect. A paraconformity occurs when there is no apparent gap, but a significant time gap exists.

(D) a nonconformity: Correct — The contact between the Talchir Formation (sedimentary) and the Precambrian basement (igneous or metamorphic) is a nonconformity.

Step 3: Conclusion.

The correct answer is **(D) a nonconformity**.

Quick Tip

Nonconformities occur when sedimentary rocks lie on top of eroded older igneous or metamorphic rocks, often indicating significant time gaps.

---

27. Increased diversity of siphonate bivalves occurred in response to

(A) the Cambrian explosion in the Paleozoic

(B) increased temperature in the Cenozoic

(C) increased predation pressure in the Mesozoic

(D) increased oxygen level in the Proterozoic

Correct Answer: (A) the Cambrian explosion in the Paleozoic

Solution:

Step 1: Understanding siphonate bivalves.

Siphonate bivalves are a group of marine organisms that evolved during the Cambrian period, which saw an explosion of biodiversity. The increase in their diversity was largely in response to the ecological changes during the Cambrian explosion.

Step 2: Analyzing the options.

(A) the Cambrian explosion in the Paleozoic: Correct — The Cambrian explosion resulted in a significant increase in the diversity of many marine organisms, including siphonate bivalves.

(B) increased temperature in the Cenozoic: Incorrect, as the Cambrian explosion predates the Cenozoic era.

(C) increased predation pressure in the Mesozoic: Incorrect, as the increased diversity occurred much earlier.

(D) increased oxygen level in the Proterozoic: Incorrect. While oxygen levels increased during the Proterozoic, the Cambrian explosion was the key event for the diversification of siphonate bivalves.

Step 3: Conclusion.

The correct answer is **(A) the Cambrian explosion in the Paleozoic**.

Quick Tip

The Cambrian explosion is one of the most important events in Earth's history, leading to the rapid diversification of life, including siphonate bivalves.

---

28. An index fossil should have

(A) large geographic range and small temporal range

(B) small geographic range and large temporal range

(C) small geographic range and small temporal range

(D) large geographic range and large temporal range

Correct Answer: (A) large geographic range and small temporal range

Solution:

Step 1: Understanding index fossils.

Index fossils are used for dating and correlating the age of rock layers. They should have a wide geographic distribution, but a narrow temporal range, so they can be used to identify a specific time period.

Step 2: Analyzing the options.

(A) large geographic range and small temporal range: Correct — This is the ideal characteristic for an index fossil. It should be found in many places but only for a short time.

(B) small geographic range and large temporal range: Incorrect, as the fossil would not be useful for correlation over large areas.

(C) small geographic range and small temporal range: Incorrect, as it would be too limited to be useful for indexing.

(D) large geographic range and large temporal range: Incorrect, as this would make the fossil less useful for precise dating.

Step 3: Conclusion.

The correct answer is **(A) large geographic range and small temporal range**.

Quick Tip

For effective index fossils, aim for organisms with a broad geographic range but a short, specific time span to help date rock layers accurately.

---

29. Match the formations in Group I with corresponding stratigraphic periods in Group II.

Group I Group II

P. Syringothyris Limestone 1. Permian

Q. Karai Shale 2. Jurassic

R. Chari 3. Carboniferous

S. Barren Measures 4. Cretaceous

(A) P-1, Q-2, R-3, S-4

(B) P-2, Q-4, R-1, S-3

(C) P-3, Q-4, R-2, S-1

(D) P-4, Q-1, R-2, S-3

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

Solution:

Step 1: Understanding stratigraphic periods.

Each rock formation corresponds to a specific geologic period, and knowing the correct match is important for understanding Earth's history.

Step 2: Analyzing the options.

(A) P-1, Q-2, R-3, S-4: Correct — Syringothyris Limestone corresponds to the Permian period, Karai Shale to the Jurassic, Chari to the Carboniferous, and Barren Measures to the Cretaceous.

(B) P-2, Q-4, R-1, S-3: Incorrect.

(C) P-3, Q-4, R-2, S-1: Incorrect.

(D) P-4, Q-1, R-2, S-3: Incorrect.

Step 3: Conclusion.

The correct answer is **(A) P-1, Q-2, R-3, S-4**.

Quick Tip

Familiarize yourself with common rock formations and their associated stratigraphic periods for easier identification in geological studies.

---

30. Which one of the given statements is correct?

(A) van der Waals bonding is absent in silicate minerals

(B) Sulfide minerals form by covalent bonding between metal and sulfur

(C) Silicate minerals have a significant component of metallic bonding

(D) Metal-sulfide formation does not involve splitting of d-orbitals

Correct Answer: (B) Sulfide minerals form by covalent bonding between metal and sulfur

Solution:

Step 1: Understanding bonding in minerals.

Minerals form based on different types of bonding, such as ionic, covalent, and metallic. Each mineral class has a characteristic bonding style.

Step 2: Analyzing the options.

(A) van der Waals bonding is absent in silicate minerals: Incorrect. While silicate minerals typically have covalent bonds, van der Waals forces can be present in some cases.

(B) Sulfide minerals form by covalent bonding between metal and sulfur: Correct — Sulfide minerals, like galena (PbS), are formed by covalent bonding between metal and sulfur atoms.

(C) Silicate minerals have a significant component of metallic bonding: Incorrect, as silicate minerals predominantly have covalent and ionic bonding, not metallic.

(D) Metal-sulfide formation does not involve splitting of d-orbitals: Incorrect. In metal-sulfide formation, the metal's d-orbitals can participate in bonding.

Step 3: Conclusion.

The correct answer is **(B) Sulfide minerals form by covalent bonding between metal and sulfur**.

Quick Tip

Sulfide minerals primarily form through covalent bonding between metal atoms and sulfur, which is different from ionic or metallic bonding.

---

31. Which of the following structures form in marine environment?

(A) Lateral accretionary surfaces

(B) Hummocky cross stratification

(C) Herringbone cross stratification

(D) Barchanoids

Correct Answer: (B) Hummocky cross stratification

Solution:

Step 1: Understanding the concept.

Sedimentary structures help determine the depositional environment. Marine environments are typically influenced by wave and storm activity, forming structures such as hummocky cross stratification (HCS).

Step 2: Analyzing the options.

(A) Lateral accretionary surfaces: Found in fluvial point bar deposits, not marine.

(B) Hummocky cross stratification: Correct — This structure forms under oscillatory wave action below fair-weather wave base during storm events, typical of shallow marine settings.

(C) Herringbone cross stratification: Occurs in tidal environments, not purely marine.

(D) Barchanoids: Form in aeolian (desert dune) environments, not marine.

Step 3: Conclusion.

The correct answer is **(B) Hummocky cross stratification**, as it is characteristic of storm-dominated shallow marine environments.

Quick Tip

Hummocky cross stratification (HCS) forms due to combined flow under storm conditions in shallow marine settings — a key indicator of marine deposition.

---

32. Identify the correct stratigraphic successions ordered from oldest to youngest.

(A) Papaghni Group - Kurnool Group - Nallamalai Group - Chitravati Group

(B) Semri Group - Kaimur Group - Rewa Group - Bhander Group

(C) Papaghni Group - Chitravati Group - Nallamalai Group - Kurnool Group

(D) Semri Group - Rewa Group - Bhander Group - Kaimur Group

Correct Answer: (C) Papaghni Group - Chitravati Group - Nallamalai Group - Kurnool Group

Solution:

Step 1: Understanding the stratigraphic framework.

The Cuddapah Basin of southern India records a long sequence of Proterozoic sedimentation. The correct chronological order of these groups is crucial for understanding geological evolution.

Step 2: Analyzing the options.

(A) Incorrect — Kurnool Group is the youngest, not placed before Nallamalai here.

(B) Refers to Vindhyan Supergroup, not the Cuddapah Basin succession.

(C) Correct — The order from oldest to youngest is Papaghni $\rightarrow$ Chitravati $\rightarrow$ Nallamalai $\rightarrow$ Kurnool.

(D) Incorrect sequence of Vindhyan groups.

Step 3: Conclusion.

Hence, the correct order is **(C) Papaghni Group - Chitravati Group - Nallamalai Group - Kurnool Group**.

Quick Tip

In Indian stratigraphy, remember the Cuddapah Basin sequence as: *Papaghni* $\rightarrow$ *Chitravati* $\rightarrow$ *Nallamalai* $\rightarrow$ *Kurnool*. It represents a transition from deep to shallow marine sedimentation.

---

33. Which of the following stratigraphic units contain coal seams?

(A) Barakar Formation

(B) Lakadong Formation

(C) Pachmarhi Formation

(D) Panchet Formation

Correct Answer: (A) Barakar Formation

Solution:

Step 1: Understanding the geological context.

The Barakar Formation is known for its thick coal seams and is part of the Gondwana sequence, primarily associated with coal deposits. The other formations listed do not have significant coal seams.

Step 2: Analyzing the options.

(A) Barakar Formation: Correct — This formation is part of the Lower Gondwana and is known for coal seams.

(B) Lakadong Formation: Contains limestone and shales, no significant coal deposits.

(C) Pachmarhi Formation: Primarily consists of fluvial deposits, no coal seams.

(D) Panchet Formation: Contains red beds and sandstone, not associated with coal.

Step 3: Conclusion.

The correct answer is **(A) Barakar Formation**, as it is the primary coal-bearing formation in the Gondwana sequence.

Quick Tip

Remember, coal seams are typically found in the Lower Gondwana formations like Barakar and Raniganj.

---

34. Which of the following statements are CORRECT?

(A) *Mytilus* represents byssally attached bivalves

(B) *Nautilus* is the only living cephalopod genus with a coiled external shell

(C) The cidaroids are the only echinoid group still living

(D) Trilobites did not moult

Correct Answer: (A) *Mytilus* represents byssally attached bivalves, and (B) *Nautilus* is the only living cephalopod genus with a coiled external shell.

Solution:

Step 1: Reviewing the statements.

(A) Correct — *Mytilus* (mussels) are byssally attached, meaning they attach to substrates with byssal threads.

(B) Correct — *Nautilus* is the only extant cephalopod with a coiled external shell, unlike other cephalopods such as squids and octopuses.

(C) Incorrect — The cidaroids are just one group of echinoids, and other groups like clypeasteroids are still alive.

(D) Incorrect — Trilobites did moult, as they are arthropods, and moulting was necessary for their growth.

Step 2: Conclusion.

The correct answer is **(A) and (B)**.

Quick Tip

In paleontology, always remember that molluscs like *Mytilus* attach using byssal threads, and the *Nautilus* is unique for its coiled shell.

---

35. Which of the following genera are stem fossils?

(A) *Dadoxylon*

(B) *Dicroidium*

(C) *Vertebraria*

(D) *Ptilophyllum*

Correct Answer: (C) *Vertebraria*

Solution:

Step 1: Identifying stem fossils.

Stem fossils represent the structural remains of the plant, particularly from plants like *Glossopteris*. The genus *Vertebraria* is a stem fossil associated with *Glossopteris*.

Step 2: Analyzing the options.

(A) *Dadoxylon* — Represents wood from extinct plants.

(B) *Dicroidium* — Leaf genus, not a stem.

(C) *Vertebraria* — Correct — Stem fossil from *Glossopteris*.

(D) *Ptilophyllum* — Leaf fossil, not a stem.

Step 3: Conclusion.

The correct answer is **(C) Vertebraria**, as it represents the stem of *Glossopteris*.

Quick Tip

In paleobotany, remember that form-genera like *Vertebraria* are stem fossils, while others like *Ptilophyllum* are leaf fossils.

---

36. Which of the following statements are correct?

(A) Abutments are the sides of the valley supporting the dam structure

(B) Spillways can control the release of water from the reservoir

(C) The toe of the dam is the upstream edge of the base of the dam structure

(D) Galleries serve as passages through the dam

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

Solution:

Step 1: Reviewing dam terminology.

Abutments support the sides of the dam, often built into the valley walls. **Spillways** are vital for controlling water discharge. **Galleries** are internal passages for inspections and drainage, while **toe** refers to the downstream edge of the dam, not upstream.

Step 2: Conclusion.

The correct answer is **(A)**, **(B)**, and **(D)**.

Quick Tip

In dam engineering, ensure you understand the key components like abutments, spillways, and galleries for dam design and maintenance.

---

37. The acceleration due to gravity on the Earth's surface depends on

(A) latitude

(B) longitude

(C) elevation

(D) topography of the surrounding terrain

Correct Answer: (C) elevation

Solution:

Step 1: Understanding gravity variation.

Gravity is influenced by the Earth's rotation, its shape, and altitude. The further you are from the center of the Earth, the weaker the gravitational pull, which is why gravity decreases with elevation.

Step 2: Analyzing the options.

(A) latitude: Gravity is stronger at the poles and weaker at the equator due to Earth's oblate spheroid shape, but it is not the primary factor.

(B) longitude: Longitude does not affect gravity.

(C) elevation: Correct — Gravity decreases with height above sea level because you are further from the Earth's center.

(D) topography of the surrounding terrain: While it can influence local variations in gravity, elevation is the key factor.

Step 3: Conclusion.

The correct answer is **(C) elevation** as it directly affects the distance from the Earth's center, which in turn affects gravitational acceleration.

Quick Tip

In geophysics, the Earth's gravity is strongest at sea level and at the poles due to both elevation and the Earth's shape.

---

38. A metamorphosed basaltic assemblage can include the minerals

(A) garnet-omphacite

(B) hornblende-plagioclase

(C) garnet-staurolite

(D) glaucophae-lawsonite

Correct Answer: (B) hornblende-plagioclase

Solution:

Step 1: Recognizing metamorphic mineral assemblages.

Metamorphosed basalt often develops minerals like hornblende (amphibole) and plagioclase under moderate to high-grade conditions, characteristic of basaltic to andesitic metamorphism.

Step 2: Analyzing the options.

(A) garnet-omphacite: Common in high-pressure metamorphism, typically in eclogites, not basalt.

(B) hornblende-plagioclase: Correct — A common metamorphic assemblage in basalt, reflecting amphibolite-grade metamorphism.

(C) garnet-staurolite: Found in high-grade metamorphic rocks but not typical of basaltic metamorphism.

(D) glaucophae-lawsonite: Occurs in high-pressure, low-temperature settings but not a typical feature of basaltic assemblages.

Step 3: Conclusion.

The correct answer is **(B) hornblende-plagioclase**, as it is a typical mineral pair in the metamorphosis of basalt.

Quick Tip

Basaltic metamorphism commonly forms hornblende and plagioclase in the amphibolite facies.

---

39. Which of the following pairs represent correct plutonic – volcanic equivalents?

(A) Granodiorite – dacite

(B) Norite – basalt

(C) Dunite – komatiite

(D) Nepheline syenite – phonolite

Correct Answer: (D) Nepheline syenite – phonolite

Solution:

Step 1: Understanding plutonic and volcanic equivalents.

Plutonic rocks are formed deep within the Earth and are typically coarse-grained, while volcanic rocks form from lava eruptions and are fine-grained. Many plutonic rocks have volcanic counterparts formed under similar conditions but on the surface.

Step 2: Analyzing the options.

(A) Granodiorite – dacite: Not correct; granodiorite is a coarse-grained plutonic rock, and dacite is a volcanic rock, but they do not directly correspond as plutonic-volcanic pairs.

(B) Norite – basalt: Norite is a type of gabbro, which is a coarse-grained plutonic rock. Basalt is the volcanic counterpart but isn't an exact pair.

(C) Dunite – komatiite: Dunite is ultramafic, rich in olivine, but does not correspond directly to komatiite.

(D) Nepheline syenite – phonolite: Correct — Nepheline syenite (plutonic) and phonolite (volcanic) are both rich in alkaline feldspar and have similar mineral compositions.

Step 3: Conclusion.

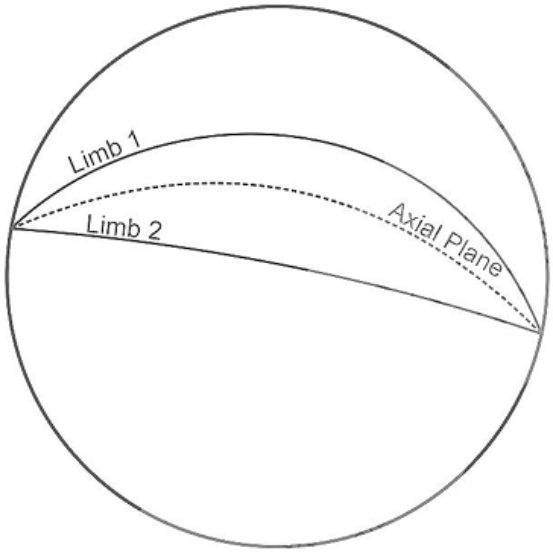
The correct answer is **(D) Nepheline syenite – phonolite**, as they are true plutonic-volcanic pairs.

Quick Tip

When studying volcanic and plutonic rocks, look for mineralogical similarities, particularly in feldspar content, to identify corresponding pairs.

---

40. Based on the given stereographic projection, the fold can be classified as



(A) reclined fold

(B) vertical fold

(C) overturned fold

(D) non-plunging fold

Correct Answer: (A) reclined fold

Solution:

Step 1: Understanding stereographic projections.

Stereographic projections are used in structural geology to represent the 3D orientation of fold axes. In this case, we observe the axial plane tilting and the limbs bending, suggesting a reclined fold.

Step 2: Analyzing the options.

(A) reclined fold: Correct — A reclined fold has an axial plane that is tilted, as shown in the projection. This causes the limbs to be inclined at an angle to each other.

(B) vertical fold: Incorrect — A vertical fold would have a vertical axial plane, which is not shown here.

(C) overturned fold: Incorrect — An overturned fold typically has limbs that are rotated beyond the vertical, which is not indicated in this projection.

(D) non-plunging fold: Incorrect — A non-plunging fold has horizontal limbs, whereas the given fold appears to be inclined.

Step 3: Conclusion.

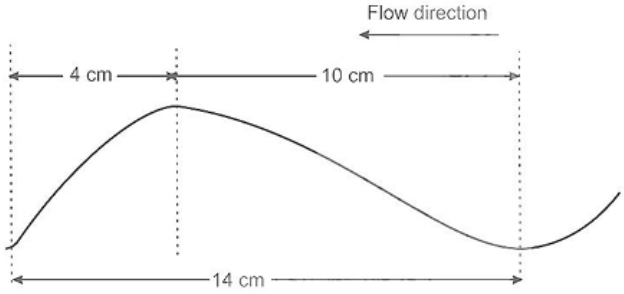
The correct answer is **(A) reclined fold**, as indicated by the axial plane's tilt and the inclination of the limbs.

Quick Tip

In stereographic projections, look for the angle of the axial plane and the inclination of the limbs to classify the fold type accurately.

---

41. The Ripple Symmetry Index (RSI) for the given hypothetical asymmetric ripple is ..... (Round off to one decimal place)



Solution:

Step 1: Understanding the Ripple Symmetry Index (RSI).

RSI is calculated as the ratio of the length of the steeper side (4 cm) to the length of the gentler side (10 cm) in an asymmetric ripple.

Step 2: RSI formula:

$$RSI = \frac{\text{Length of steeper side}}{\text{Length of gentler side}} = \frac{4}{10} = 0.4$$

Step 3: Conclusion.

The Ripple Symmetry Index (RSI) for the given ripple is **0.4**.

Quick Tip

RSI is a useful tool in sedimentology to measure the asymmetry of ripple marks, indicating flow strength and sediment movement direction.

42. Within a fourth-order drainage basin, the total lengths of the 1st, 2nd, 3rd, and 4th order streams are 10.5 km, 7.5 km, 5.5 km, and 1.5 km, respectively. If the drainage density of the basin is 0.5 km^{-1}, the basin area is ..... km^2.

Solution:

Step 1: Drainage Density Formula.

Drainage density is calculated as the total stream length divided by the basin area:

$$\text{Drainage density} = \frac{\text{Total stream length}}{\text{Basin area}}$$

Step 2: Calculate the total stream length.

$$\text{Total stream length} = 10.5 + 7.5 + 5.5 + 1.5 = 25\,\text{km}$$

Step 3: Rearranging the formula to find the basin area.

$$\text{Basin area} = \frac{\text{Total stream length}}{\text{Drainage density}} = \frac{25}{0.5} = 50\,\text{km}^2$$

Step 4: Conclusion.

The basin area is **50 km^2**.

Quick Tip

Drainage density is a measure of how much water is carried by a stream network per unit area and is important for hydrological studies.

---

43. A soil has a void ratio of 0.5. The total porosity of the soil is ..... (Round off to two decimal places)

Solution:

Step 1: Understanding the relationship between void ratio and porosity.

The relationship between void ratio e and porosity ϕ is given by the formula:

$$\phi = \frac{e}{1+e}$$

where e is the void ratio.

Step 2: Applying the formula. Given $e = 0.5$, we substitute into the formula:

$$\phi = \frac{0.5}{1 + 0.5} = \frac{0.5}{1.5} = 0.3333$$

Step 3: Conclusion.

The total porosity of the soil is **33.33%**.

> **Quick Tip**
>
> To calculate porosity, use the formula $\phi = \frac{e}{1+e}$, where e is the void ratio.

---

44. The average unit weight of the uppermost part of the crust is 25000 N/m^3. The vertical stress at a depth of 1 km would be

$$_{M}{}^{Pa.(Ininteger)}$$

Solution:

Step 1: Understanding the relationship between vertical stress and depth.

Vertical stress at a depth can be calculated using the formula:

$$\sigma = \gamma \times h$$

where: - σ is the vertical stress, - γ is the unit weight of the material (25000 N/m^3), - h is the depth (1 km or 1000 m).

Step 2: Convert the units.

To convert the stress from N/m^2 to MPa (1 MPa = 10^6 N/m^2), we perform the calculation:

$$\sigma = 25000 \times 1000 = 25,000,000\,\text{N/m}^2$$

$$\sigma = \frac{25,000,000}{10^6} = 25\,\text{MPa}$$

Step 3: Conclusion.

The vertical stress at a depth of 1 km is **25 MPa**.

Quick Tip

In geological stress calculations, the unit weight of the material multiplied by depth gives the vertical stress. Always convert units appropriately to match the desired stress unit.

---

45. The radius of the Earth's circular orbit round the Sun is 149×10^6 km. The Earth takes 365 days to orbit the Sun. The tangential velocity of the Earth is

$_k m/hour. (=3.14)(Roundoff to one decimal place)$

Solution:

Step 1: Understanding the formula for tangential velocity.

The tangential velocity v can be calculated using the formula for circular motion:

$$v = \frac{2\pi r}{T}$$

where: - r is the radius of the orbit (149×10^6 km), - T is the period of revolution (365 days, converted to hours), - π is given as 3.14.

Step 2: Convert the period to hours.

$$T = 365 \times 24 = 8760 \, \text{hours}$$

Step 3: Apply the values to the formula.

$$v = \frac{2 \times 3.14 \times 149 \times 10^6}{8760}$$

$$v = \frac{937,948,000}{8760} = 107,018.4 \, \text{km/hour}$$

Step 4: Conclusion.

The tangential velocity of the Earth is **107,018.4 km/hour**.

Quick Tip

For circular motion, use the formula $v = \frac{2\pi r}{T}$, where r is the radius and T is the period of revolution. Remember to convert units when necessary.

46. A borehole inclined at 60° to the horizontal pierces a vertical basaltic dyke of uniform thickness. If the length of the basaltic drill core along the core axis is 12 m, the thickness of the dyke is

$_{m.(Ininteger)}$

Solution:

Step 1: Understanding the relationship between the length of the drill core and the dyke thickness.

The length of the drill core along the borehole axis (L) is the hypotenuse of a right triangle formed with the vertical thickness of the dyke (T) and the angle of inclination (60°).

We use trigonometry to find T:

$$L = \frac{T}{\cos(\theta)}$$

where: - $L = 12\,\text{m}$ is the length of the drill core, - $\theta = 60^\circ$ is the angle of inclination, - T is the thickness of the dyke.

Step 2: Rearranging the formula.

$$T = L \times \cos(\theta)$$

Step 3: Apply the values.

$$T = 12 \times \cos(60^\circ) = 12 \times 0.5 = 6\,\text{m}$$

Step 4: Conclusion.

The thickness of the dyke is **6 m**.

Quick Tip

To find the true thickness of a dyke or bed cut by an inclined borehole, use trigonometry: $T = L \times \cos(\theta)$, where θ is the angle of inclination.

---

47. A P-ray arrives at the mantle-core boundary at an angle 25° with respect to the normal. At what angle to the normal does it enter the core? (P-wave velocity in the lower mantle is 13.7 km/s and outer core is 8.1 km/s) (Round off to two decimal places)

Solution:

Step 1: Using Snell's Law of refraction.

Snell's Law for seismic waves is given by:

$$\frac{\sin(\theta_1)}{\sin(\theta_2)} = \frac{v_1}{v_2}$$

where: - $\theta_1 = 25^\circ$ is the angle of incidence in the lower mantle, - $v_1 = 13.7\,\text{km/s}$ is the P-wave velocity in the lower mantle, - $v_2 = 8.1\,\text{km/s}$ is the P-wave velocity in the outer core, - θ_2 is the angle of refraction in the outer core, which we need to find.

Step 2: Rearranging Snell's Law.

$$\sin(\theta_2) = \frac{v_1}{v_2} \times \sin(\theta_1)$$

Step 3: Applying the values.

$$\sin(\theta_2) = \frac{13.7}{8.1} \times \sin(25^\circ) = 1.69 \times 0.4226 = 0.714$$

$$\theta_2 = \sin^{-1}(0.714) = 45.56^\circ$$

Step 4: Conclusion.

The angle at which the P-ray enters the core is **45.56**°.

Quick Tip

Use Snell's Law for seismic waves to calculate the refracted angle: $\frac{\sin(\theta_1)}{\sin(\theta_2)} = \frac{v_1}{v_2}$, where θ_1 is the angle of incidence and v_1, v_2 are the wave velocities.

---

48. The mass of the Earth is 80 times that of the Moon while the radius of the Earth is four times that of the Moon. The surface gravity of the Earth is ..... times that of the Moon? (In integer)

Solution:

Step 1: Understanding the formula for surface gravity.

The formula for surface gravity g is given by:

$$g = \frac{GM}{R^2}$$

where: - G is the gravitational constant,

- M is the mass of the celestial body,

- R is the radius of the celestial body.

The surface gravity is directly proportional to mass and inversely proportional to the square of the radius.

Step 2: Comparing the surface gravity of the Earth and the Moon.

Let the surface gravity of the Moon be g_{Moon} and the surface gravity of the Earth be g_{Earth}.

$$g_{\text{Earth}} = \frac{M_{\text{Earth}}}{R_{\text{Earth}}^2} \quad \text{and} \quad g_{\text{Moon}} = \frac{M_{\text{Moon}}}{R_{\text{Moon}}^2}$$

Since: - $M_{\text{Earth}} = 80 \times M_{\text{Moon}}$, - $R_{\text{Earth}} = 4 \times R_{\text{Moon}}$,

$$g_{\text{Earth}} = \frac{80 \times M_{\text{Moon}}}{(4 \times R_{\text{Moon}})^2} = \frac{80 \times M_{\text{Moon}}}{16 \times R_{\text{Moon}}^2} = 5 \times g_{\text{Moon}}$$

Step 3: Conclusion.

The surface gravity of the Earth is **5 times** that of the Moon.

Quick Tip

Surface gravity is proportional to mass and inversely proportional to the square of the radius. Always use this formula for gravity comparisons.

---

49. A hypothetical rock contains the assemblage kyanite, sillimanite, and quartz. The variance (degree of freedom) of the assemblage is ..... (In integer)

Solution:

Step 1: Understanding the degree of freedom.

The degree of freedom in a mineral assemblage can be calculated using the Gibbs phase rule, which is given by:

$$F = C - P + 2$$

where: - F is the degree of freedom,

- C is the number of components,

- P is the number of phases.

In this case:

- $C = 3$ (kyanite, sillimanite, and quartz),

- $P = 1$ (since only one phase of each mineral is present).

Step 2: Applying the formula.

$$F = 3 - 1 + 2 = 4$$

Step 3: Conclusion.

The variance (degree of freedom) of the assemblage is **4**.

Quick Tip

Use Gibbs phase rule for calculating degrees of freedom: $F = C - P + 2$, where C is components and P is phases.

---

50. The cut-off grade of copper is 0.45 wt%. A mine has 1 million tonne of waste with a grade of 0.25 wt%. The mine also has stock of high-grade ore with a grade of 1.8 wt%. How much of this high-grade ore (in million tonne) must be blended with the waste to sell the blended ore at a grade of 0.5 wt%? (Round off to three decimal places)

Solution:

Step 1: Define variables and set up the equation.

Let x be the amount of high-grade ore to be blended with the waste. The mass balance equation for the copper content in the ore can be written as:

$$0.25 \times 1 + 1.8 \times x = 0.5 \times (1 + x)$$

where: - 0.25×1 is the copper content in 1 million tonne of waste, - $1.8 \times x$ is the copper content in x million tonne of high-grade ore, - $0.5 \times (1 + x)$ is the copper content in the blended ore.

Step 2: Simplify the equation.

$$0.25 + 1.8x = 0.5 + 0.5x$$

Step 3: Solve for x.

$$1.8x - 0.5x = 0.5 - 0.25$$

$$1.3x = 0.25$$

$$x = \frac{0.25}{1.3} = 0.1923$$

Step 4: Conclusion.

To achieve a blended grade of 0.5 wt%, **0.192 million tonnes** of high-grade ore must be blended with the waste.

> Quick Tip
>
> In blending problems, use mass balance equations to account for the copper content in each material, and solve for the unknown quantity.

---

51. The maximum and minimum principal stresses in a zone of active normal faulting are 28 MPa and 8 MPa, respectively. The fault plane strikes N30°E and dips 60° towards SE. Considering Anderson's theory of faulting, the normal stress on the fault plane is ..... MPa. (In integer)

Solution:

Step 1: Understanding Anderson's theory of faulting.

Anderson's theory of faulting states that the normal stress on the fault plane is given by:

$$\sigma_n = \frac{1}{2}(\sigma_1 - \sigma_3)\left(1 - \sin^2(\theta)\right)$$

where: - σ_1 is the maximum principal stress (28 MPa), - σ_3 is the minimum principal stress (8 MPa), - θ is the angle of the fault plane with respect to the direction of maximum stress, given by the dip angle of the fault (60°).

Step 2: Calculate the normal stress.

$$\sigma_n = \frac{1}{2}(28 - 8)\left(1 - \sin^2(60^\circ)\right)$$

$$\sigma_n = \frac{1}{2}(20)\left(1 - 0.75\right) = 10 \times 0.25 = 2.5\,\text{MPa}$$

Step 3: Conclusion.

The normal stress on the fault plane is **2.5 MPa**.

Quick Tip

In faulting problems, Anderson's theory helps estimate the normal stress by using the difference between the maximum and minimum principal stresses.

---

52. A granite block starts sliding on a slope (inclination of 30° with the horizontal) under the effect of gravity only, along the true direction of inclination of the slope and hits the ground in 4 seconds. Considering zero friction and zero cohesion during sliding, the vertical height of the point (with respect to the ground) from where the block was dislodged is ..... m. (g = 10 m/s^2)

Solution:

Step 1: Understand the problem setup.

The block is sliding under the effect of gravity along a slope. The motion is along the inclined plane, and we are asked to calculate the vertical height from which the block was dislodged. We can use kinematic equations to calculate this.

The block slides down a slope with gravity acting vertically. The time taken to hit the ground is 4 seconds. We can decompose the motion into horizontal and vertical components.

Step 2: Use the kinematic equation for vertical motion. The vertical displacement h can be found using the equation:

$$h = \frac{1}{2}gt^2$$

where: - $g = 10\,\text{m/s}^2$ (acceleration due to gravity), - $t = 4\,\text{seconds}$ (time taken).

Step 3: Calculate the vertical height.

$$h = \frac{1}{2} \times 10 \times 4^2 = 5 \times 16 = 80\,\text{m}$$

Step 4: Conclusion.

The vertical height from which the block was dislodged is **80 m**.

Quick Tip

In free-fall motion, use the kinematic equation $h = \frac{1}{2}gt^2$ to calculate vertical displacement, where g is the acceleration due to gravity and t is the time of fall.

---

53. A cylindrical soil sample is encased in an open-ended inclined tube with a diameter of 100 mm. There is a constant supply of water from the upper end of the sample and the outflow from the other end is collected in a beaker. The average amount of water collected is 1000 mm^3 every 10 seconds. The average outflow velocity is ..... mm/sec. ($\pi = 3.14$) **(Round off to three decimal places)**

Solution:

Step 1: Understanding the outflow velocity.

The outflow velocity v is given by:

$$v = \frac{\text{Volume of water collected}}{\text{Area of cross-section} \times \text{Time interval}}$$

where: - Volume of water collected = 1000 mm^3, - Time interval = 10 seconds, - The cross-sectional area of the tube is given by $A = \pi r^2$, where r is the radius of the tube.

Step 2: Calculate the radius of the tube. Given the diameter is 100 mm, the radius $r = \frac{100}{2} = 50\,\text{mm}$.

Step 3: Calculate the area of cross-section.

$$A = \pi r^2 = 3.14 \times 50^2 = 3.14 \times 2500 = 7850\,\text{mm}^2$$

Step 4: Calculate the outflow velocity.

$$v = \frac{1000}{7850 \times 10} = \frac{1000}{78500} = 0.0127\,\text{mm/sec}$$

Step 5: Conclusion.

The average outflow velocity is **0.0127 mm/sec**.

Quick Tip

To calculate the outflow velocity, divide the volume of water collected by the cross-sectional area of the tube and the time interval. Always ensure units are consistent.

54. Using Airy's hypothesis, calculate the thickness of the root beneath a 4 km high mountain in isostatic equilibrium with a 40 km thick continental crust of density 2800 kg/m^3 and a mantle of density 3300 kg/m^3. Express your answer in km. (Round off to one decimal place)

Solution:

Step 1: Understand Airy's hypothesis.

Airy's hypothesis states that the height of a mountain is supported by the displacement of the crust below it, known as the "root." The relationship between the height of the mountain, the densities of the crust and mantle, and the thickness of the root is given by:

$$H = \frac{d_c \cdot (H + R)}{d_m - d_c}$$

where: - H is the height of the mountain (4 km), - R is the thickness of the root (which we need to find), - d_c is the density of the crust (2800 kg/m^3), - d_m is the density of the mantle (3300 kg/m^3).

Step 2: Apply the known values. We are given: - $H = 4\,\text{km}$, - $d_c = 2800\,\text{kg/m}^3$, - $d_m = 3300\,\text{kg/m}^3$, - The thickness of the crust is 40 km.

Rearranging the formula to solve for R:

$$R = \frac{d_m \cdot H}{d_m - d_c} - H$$

Substitute the known values:

$$R = \frac{3300 \times 4}{3300 - 2800} - 4 = \frac{13200}{500} - 4 = 26.4 - 4 = 22.4\,\text{km}$$

Step 3: Conclusion.

The thickness of the root beneath the mountain is **22.4 km**.

Quick Tip

Airy's hypothesis helps in understanding isostatic equilibrium by calculating the thickness of the "root" beneath mountains. Use the relationship between densities and heights to find the root thickness.

55. Given atomic weights of Cu, Fe, and S as 63.55, 55.85, 32.10, respectively, find out the weight of copper (in gram) metal in an ore (no associated gangue) of 1 kg weight constituting of bornite, chalcopyrite and chalcocite present in weight fractions of 0.4, 0.4 and 0.2, respectively. (Round off to one decimal place)

Solution:

Step 1: Understand the composition of the ore.

The ore consists of: - Bornite, - Chalcopyrite, - Chalcocite.

The weight fractions of these minerals in the ore are 0.4, 0.4, and 0.2, respectively.

Step 2: Calculate the copper content in each mineral.

The copper content in each mineral can be calculated using the molecular formula and the atomic weights: - Bornite ($Cu_5Fe_2S_4$): The molar mass of bornite is calculated from the atomic weights of Cu (63.55 g/mol), Fe (55.85 g/mol), and S (32.10 g/mol):

Molar mass of bornite $= 5\times63.55+2\times55.85+4\times32.10 = 317.75+111.7+128.4 = 557.85$ g/mol

The copper content in bornite is:

$$\frac{5 \times 63.55}{557.85} = 0.570 \text{ or } 57.0\%$$

- Chalcopyrite ($CuFeS_2$): The molar mass of chalcopyrite is:

Molar mass of chalcopyrite $= 63.55 + 55.85 + 2 \times 32.10 = 63.55 + 55.85 + 64.2 = 183.60$ g/mol

The copper content in chalcopyrite is:

$$\frac{63.55}{183.60} = 0.346 \text{ or } 34.6\%$$

- Chalcocite (Cu_2S): The molar mass of chalcocite is:

$$\text{Molar mass of chalcocite} = 2 \times 63.55 + 32.10 = 127.10 + 32.10 = 159.20 \text{ g/mol}$$

The copper content in chalcocite is:

$$\frac{2 \times 63.55}{159.20} = 0.797 \text{ or } 79.7\%$$

Step 3: Calculate the total weight of copper in 1 kg of ore.

Now we calculate the total copper weight in 1 kg of ore by multiplying the weight fractions by the copper contents in each mineral:

$$\text{Copper in bornite} = 1 \times 0.4 \times 0.570 = 0.228\,\text{kg}$$

$$\text{Copper in chalcopyrite} = 1 \times 0.4 \times 0.346 = 0.1384\,\text{kg}$$

$$\text{Copper in chalcocite} = 1 \times 0.2 \times 0.797 = 0.1594\,\text{kg}$$

Step 4: Add the copper weights.

$$\text{Total copper} = 0.228 + 0.1384 + 0.1594 = 0.5258\,\text{kg} = 525.8\,\text{grams}$$

Step 5: Conclusion.

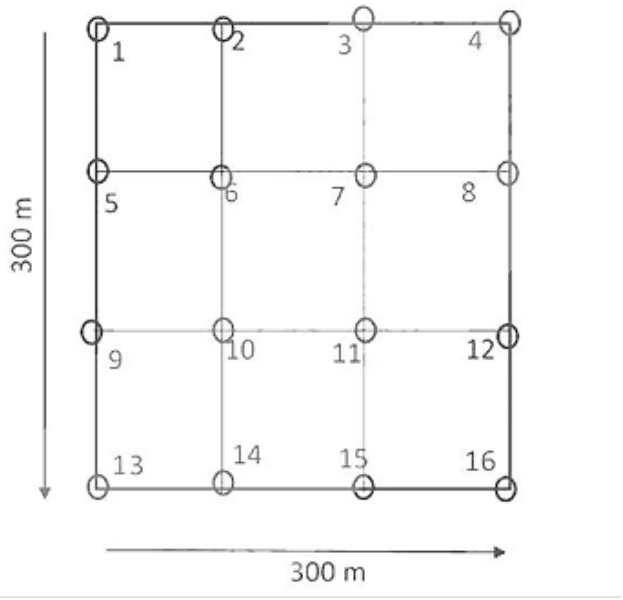
The weight of copper in 1 kg of the ore is **525.8 grams**.

Quick Tip

To find the copper content in an ore, calculate the molar mass of each mineral, find the copper percentage, then use the weight fraction of each mineral in the total ore to calculate the total copper content.

---

56. An ore body defined by a 300 m $\times$ 300 m area is shown in the figure in which the drill hole locations on equally spaced square grid are marked (numbers 1–16). The average thickness of the ore body at the 4 interior points is 10.8 m, at the 4 corners is 11.0 m and at the remaining 8 boundary locations is 10.5 m, respectively. The corresponding average grades are 1.5, 1.9 and 1.8 wt% respectively. Calculate the average grade (in wt%) of the full ore body using the Included Area Method. (Round off to two decimal places).



Solution:

Step 1: Understand the Included Area Method.

The Included Area Method is used to calculate the average grade of an ore body using a grid. The average grade of the whole area is calculated by taking the weighted average of the grades at the drill hole locations, with each point weighted by the area it represents.

We are given: - 4 interior points with a thickness of 10.8 m and grade of 1.5 wt%, - 8 boundary points with a thickness of 10.5 m and grade of 1.8 wt%, - 4 corner points with a thickness of 11.0 m and grade of 1.9 wt%.

Step 2: Assign the weights to the points.

For each location, the weight is proportional to the area represented by the grid point. Each point represents a 100 m $\times$ 100 m square. Therefore: - The interior points are assigned a weight of 1, - The boundary points are assigned a weight of 0.5 (half of the interior), - The corner points are assigned a weight of 0.25 (a quarter of the interior).

Step 3: Calculate the weighted average grade.

We calculate the total grade by summing the weighted grades at all points:

$$\text{Weighted Grade} = \frac{(4 \times 10.8 \times 1.5) + (8 \times 10.5 \times 1.8) + (4 \times 11.0 \times 1.9)}{4 \times 10.8 + 8 \times 10.5 + 4 \times 11.0}$$

Breaking it down:

$$\text{Numerator} = (4 \times 1.5 \times 10.8) + (8 \times 1.8 \times 10.5) + (4 \times 1.9 \times 11.0) = 64.8 + 151.2 + 83.6 = 299.6$$

$$\text{Denominator} = (4 \times 10.8) + (8 \times 10.5) + (4 \times 11.0) = 43.2 + 84 + 44 = 171.2$$

$$\text{Average Grade} = \frac{299.6}{171.2} = 1.75\,\text{wt\%}$$

Step 4: Conclusion.

The average grade of the full ore body is **1.75 wt%**.

Quick Tip

In the Included Area Method, each drill hole is weighted according to its area in the grid. The total grade is the weighted average of these grades.

---

57. The ^{87}Sr/^{86}Sr ratio of a 1000 Ma granite was measured as 0.8001. If its ^{87}Rb/^{86}Sr ratio is 2.499, what was the Sr isotopic ratio of the source at the time of derivation of the granite? (Decay constant of ^{87}Rb = 1.39×10^{-11} yr^{-1}) (Round off to three decimal places)

Solution:

Step 1: Understand the equation for Sr isotopic ratio.

The formula for the change in the ^{87}Sr/^{86}Sr ratio over time is:

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}} = \frac{^{87}\text{Sr}}{^{86}\text{Sr}_0} + \left(\frac{^{87}\text{Rb}}{^{86}\text{Sr}}\right)\left(e^{\lambda t} - 1\right)$$

where: - $\frac{^{87}\text{Sr}}{^{86}\text{Sr}}$ is the measured ratio (0.8001), - $\frac{^{87}\text{Rb}}{^{86}\text{Sr}}$ is the ratio of ^{87}Rb/^{86}Sr (2.499), - λ is the decay constant of ^{87}Rb (1.39×10^{-11} yr^{-1}), - t is the time (1000 Ma or 1×10^9 years).

Step 2: Rearranging the equation. We need to solve for the initial Sr isotopic ratio ($\frac{^{87}\text{Sr}}{^{86}\text{Sr}_0}$):

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}_0} = \frac{^{87}\text{Sr}}{^{86}\text{Sr}} - \left(\frac{^{87}\text{Rb}}{^{86}\text{Sr}}\right)\left(e^{\lambda t} - 1\right)$$

Step 3: Substitute the values. First, calculate $e^{\lambda t} - 1$:

$$e^{\lambda t} = e^{1.39 \times 10^{-11} \times 1 \times 10^9} = e^{13.9} \approx 1.022$$

$$e^{\lambda t} - 1 = 1.022 - 1 = 0.022$$

Now, substitute into the equation:

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}_0} = 0.8001 - 2.499 \times 0.022$$

$$\frac{^{87}\text{Sr}}{^{86}\text{Sr}_0} = 0.8001 - 0.05498 = 0.7451$$

Step 4: Conclusion.

The Sr isotopic ratio of the source at the time of derivation of the granite was **0.745**.

> **Quick Tip**
>
> In radiogenic isotopic dating, the formula involving the decay constant and the isotopic ratio allows you to calculate the initial isotopic ratio at the time of rock formation.

---

58. The coefficients of permeability of two aquifers - 1 and 2, are 60 m/day and 40 m/day, respectively. Their saturated thicknesses are 30 m and 15 m, respectively. Assuming steady state Darcian flow, the transmissivity of aquifer 1 is

$_{t}imesthatofaquifer2.(Ininteger)$

Solution:

Step 1: Understanding transmissivity.

Transmissivity T is the product of the coefficient of permeability K and the saturated thickness b of the aquifer:

$$T = K \times b$$

Step 2: Calculate the transmissivities of both aquifers.

For aquifer 1:

$$T_1 = 60\,\text{m/day} \times 30\,\text{m} = 1800\,\text{m}^2/\text{day}$$

For aquifer 2:

$$T_2 = 40\,\text{m/day} \times 15\,\text{m} = 600\,\text{m}^2/\text{day}$$

Step 3: Calculate the ratio of transmissivity.

$$\frac{T_1}{T_2} = \frac{1800}{600} = 3$$

Step 4: Conclusion.

The transmissivity of aquifer 1 is **3 times** that of aquifer 2.

Quick Tip

Transmissivity is an important parameter in groundwater flow problems, and it is calculated as the product of permeability and saturated thickness of the aquifer.

---

59. Assume that ^{218}Po, with a half-life of 138 days, is in secular equilibrium with ^{238}U whose half-life is 4.5×10^9 years. How many grams of ^{218}Po will be present for each gram of ^{238}U in the mineral? Express your answer in logarithm (to the base 10). (Round off to two decimal places)

Solution:

Step 1: Understanding secular equilibrium.

In secular equilibrium, the decay rate of the parent isotope is equal to the decay rate of the daughter isotope. The number of atoms of the daughter isotope is related to the number of atoms of the parent isotope through their decay constants λ.

The relationship between the amounts of ^{238}U and ^{218}Po in secular equilibrium is:

$$\frac{N_{\text{Po}}}{N_{\text{U}}} = \frac{\lambda_{\text{Po}}}{\lambda_{\text{U}}}$$

where: - λ_{Po} and λ_{U} are the decay constants for ^{218}Po and ^{238}U, respectively.

Step 2: Calculate the decay constants. The decay constant λ is related to the half-life $t_{1/2}$ by:

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

For ^{238}U:

$$\lambda_{\text{U}} = \frac{\ln(2)}{4.5 \times 10^9 \,\text{years}} = \frac{0.693}{4.5 \times 10^9} = 1.54 \times 10^{-10} \,\text{yr}^{-1}$$

For ^{218}Po:

$$\lambda_{\text{Po}} = \frac{\ln(2)}{138 \,\text{days}} = \frac{0.693}{138} = 5.02 \times 10^{-3} \,\text{day}^{-1}$$

We need to convert λ_{Po} from days^{-1} to years^{-1} by multiplying by the number of days in a year:

$$\lambda_{\text{Po}} = 5.02 \times 10^{-3} \times 365 = 1.83 \times 10^{-1} \,\text{yr}^{-1}$$

Step 3: Calculate the ratio of ^{218}Po to ^{238}U. Now, we can calculate the ratio of the amounts of ^{218}Po and ^{238}U:

$$\frac{N_{\text{Po}}}{N_{\text{U}}} = \frac{1.83 \times 10^{-1}}{1.54 \times 10^{-10}} = 1.19 \times 10^{9}$$

Step 4: Express the result in logarithmic form. The final answer in logarithmic form (base 10) is:

$$\log_{10}(1.19 \times 10^{9}) = 9.075$$

Step 5: Conclusion.

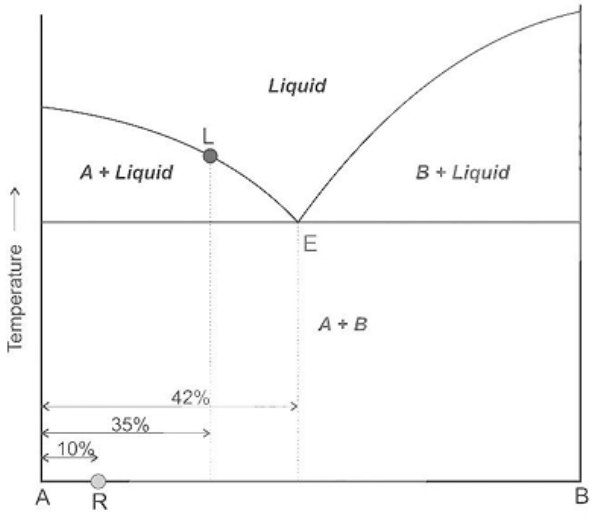
The logarithmic ratio of ^{218}Po to ^{238}U is **9.08**.

Quick Tip

In secular equilibrium, the ratio of daughter to parent isotopes is determined by their respective decay constants. Use the decay constant equation and logarithms to calculate the ratio.

---

60. The figure below is an isobaric binary temperature-composition (T-X) plot. What amount (in %) of the equilibrium melting of rock R will generate a melt of composition L? (Round off to one decimal place)



Solution:

Step 1: Analyze the T-X diagram.

The plot shows the equilibrium melting of rock R in a binary system with components A and B. The system follows the lever rule for calculating the amount of each phase in the melt. The lever rule formula is:

$$f_{\mathrm{L}} = \frac{X_R - X_0}{X_1 - X_0}$$

where: - f_{L} is the fraction of liquid, - X_R is the composition of the starting rock R, - X_0 is the composition of the liquid at the eutectic point, - X_1 is the composition of the solid (end-member composition A or B).

Step 2: Identify key points from the plot.

From the plot, the following points are identified: - The composition of rock R is 35% A. - The composition of the liquid L is at the point marked on the diagram, where the melt composition corresponds to approximately 42% A. - The eutectic composition X_0 is the point where the phase transition happens, and it has a composition of approximately 10% A.

Step 3: Apply the lever rule to find the fraction of the melt.

Now we apply the lever rule to find the fraction of the melt:

$$f_{\mathrm{L}} = \frac{X_R - X_0}{X_1 - X_0} = \frac{35 - 10}{42 - 10} = \frac{25}{32} = 0.78125$$

Step 4: Calculate the percentage of the melt. Multiplying the fraction by 100 gives the percentage:

$$f_{\mathrm{L}} \times 100 = 0.78125 \times 100 = 78.1\%$$

Step 5: Conclusion.

The amount of equilibrium melting of rock R that will generate a melt of composition L is **78.1%**.

Quick Tip

Use the lever rule to calculate the fraction of phases in a binary system based on their compositions. The formula involves the composition of the starting rock, the liquid, and the solid phases.