BSB ROUND 13

TOSS-UP

1) Chemistry – *Short Answer*   Rank the following three hydrogen atoms in terms of increasing pKa: 1) Hydrogen alpha to aldehyde carbonyl group; 2) Hydrogen alpha to ester carbonyl group; 3) Hydrogen alpha to ketone carbonyl group.

ANSWER: 1, 3, 2

BONUS

1) Chemistry – *Short Answer*   A three-level system with equal energy spacing is in contact with a heat bath. At equilibrium, if there are 400 particles in the ground state, and 16 particles in the second excited state, how many particles are in the first excited state?

ANSWER: 80

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TOSS-UP

2) Energy – *Multiple Choice*   Scientists in the Garcia Lab at UC Berkeley are studying the central dogma in embryonic development in fruit flies. Which of the following techniques can be used to identify the TATA binding protein at TATA-boxes?

W) Luciferase reporter assay
X) RNA-seq
Y) ChIP-exo
Z) DNase hypersensitivity

ANSWER: Y) CHIP-EXO

BONUS

2) Energy – *Short Answer*   Researchers in the Hartwig Group at UC Berkeley have been investigating the Buchwald-Hartwig cross-coupling reaction to better understand its mechanism. In this reaction, a palladium catalyst combines with an aryl halide via what organometallic mechanistic step?

ANSWER: OXIDATIVE ADDITION (ACCEPT: OXIDATIVE INSERTION)

TOSS-UP

3) Earth and Space – *Short Answer*   What layer of the sun separates the corona from the chromosphere and is characterized by a rapid temperature increase from 6,000 to more than a million kelvins?

ANSWER: TRANSITION REGION

BONUS

3) Earth and Space – *Multiple Choice*   While all of the following factors impact the evolution of a star, which one has the MOST significant effect on its final fate?

W) Its rotation rate
X) Its distance from other stars in the galaxy
Y) Its magnetic field strength
Z) Its metallicity

ANSWER: Z) ITS METALLICITY

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TOSS-UP

4) Math – *Short Answer*   If $f(x) = 4x^2 - 5x + 14$ and $g(x) = 2x^2$, what is $g(f(2))$?

ANSWER: 800

BONUS

4) Math – *Short Answer*   What is the sum of the largest prime palindrome that is 3 digits and the smallest prime palindrome that is 3 digits?

ANSWER: 1,030

TOSS-UP

5) Physics – *Short Answer*   The partial derivative of energy with respect to entropy at constant volume is defined as what thermodynamic quantity?

ANSWER: TEMPERATURE

BONUS

5) Physics – *Short Answer*   Rank the following three portions on a constant-pressure heating curve of water in terms of increasing slope: 1) Heating of ice before melting; 2) Melting of ice; 3) Heating of liquid water before vaporization.

ANSWER: 2, 3, 1

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TOSS-UP

6) Biology – *Short Answer*   Order the following three stages of oogenesis from first to last: 1) Primary oocyte *[OH-uh-site]*; 2) Secondary oocyte; 3) Oogonium *[oh-uh-GOH-nee-uhm]*.

ANSWER: 3, 1, 2

BONUS

6) Biology – *Short Answer*   Identify all of the following three statements that are true regarding cystic fibrosis: 1) Cystic fibrosis is caused by a mutation in a sodium transport protein; 2) Cystic fibrosis is an autosomal recessive disorder; 3) Cystic fibrosis only affects the lungs.

ANSWER: 2 ONLY

TOSS-UP

7) Earth and Space – *Short Answer*   What type of continental margins are found in areas where oceanic lithosphere is being subducted beneath the leading edge of a continent?

ANSWER: ACTIVE

BONUS

7) Earth and Space – *Multiple Choice*   Which of the following oceanic depositional features is a ridge of sand that connects an island to the mainland or to another island?

W) Baymouth bar
X) Tombolo
Y) Spit
Z) Barrier island

ANSWER: X) TOMBOLO

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TOSS-UP

8) Physics – *Multiple Choice*   Which of the following quantities, in meters, is closest to the mean free path of electrons in silicon at room temperature?

W) 10^{-12}
X) 10^{-10}
Y) 10^{-8}
Z) 10^{-6}

ANSWER: Y) 10^{-8}

BONUS

8) Physics – *Short Answer*   Consider a one-dimensional isolated Ising chain of five spins oriented up, down, down, up, down, respectively. Assume that spins on the ends of the chain interact with each other. If the coupling constant is given by *J*, then in terms of *J*, what is the magnitude of the potential energy of the system?

ANSWER: 3*J*

TOSS-UP

9) Biology – *Multiple Choice*   Which of the following is NOT an outcome of inflammation?

W) Cytokine and chemokine production
X) Vasodilation
Y) Increased vascular permeability
Z) Opsonization

ANSWER: Z) OPSONIZATION

BONUS

9) Biology – *Multiple Choice*   During cell division, cyclin B is marked for destruction by which of the following?

W) p53
X) MAP kinase
Y) Maturation promoting factor
Z) Anaphase promoting complex

ANSWER: Z) ANAPHASE PROMOTING COMPLEX

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TOSS-UP

10) Chemistry – *Short Answer*   2-chloroethyl methyl sulfide readily undergoes an intramolecular reaction to expel a chloride leaving group, forming a sulfur-containing ring of how many atoms?

ANSWER: THREE

BONUS

10) Chemistry – *Short Answer*   The Zimmerman-Traxler model is used to predict the stereochemistry of products for what class of reactions?

ANSWER: ALDOL REACTIONS

TOSS-UP

11) Energy – *Multiple Choice*   Researchers at UC Berkeley's Sarpong Group have been developing ways to make cyclic amides, or lactams, in a stereoselective manner. One of the reactions they are using is the Norrish reaction, in which a carbonyl is excited by UV light to undergo a radical decomposition. Which of the following electronic transitions is most likely the first step?

W) N to sigma star
X) Pi to sigma star
Y) N to pi star
Z) Pi to pi star

ANSWER: Y) N TO PI STAR

BONUS

11) Energy – *Short Answer*   Scientists in the Abel Group at UC Berkeley have studied the potential use of polyacetals as electrolytes in batteries. Assuming the electrochemical reaction has zeroth order kinetics, if changing the electrolyte doubles the overall rate while reducing the battery life to one third the original battery life, what would the operating voltage be scaled by?

ANSWER: 3/2

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TOSS-UP

12) Math – *Short Answer*   How many ways are there to rearrange the letters in the word BERKELEY?

ANSWER: 6720

BONUS

12) Math – *Short Answer*   What is the determinant of 3 by 3 matrix with top row (6, 1, 1), middle row (4, −2, 5), and bottom row (2, 8, 7)?

ANSWER: −306

13) Chemistry – *Short Answer*   What functional group is formed in the reaction of an amide with an excess of lithium aluminum hydride?

ANSWER: AMINE

BONUS

13) Chemistry – *Short Answer*   Identify all of the following three tetrahedral complexes that are high-spin: 1) Fe-Cl-four-two-minus; 2) Fe-I-four-two-minus; 3) Fe-SCN-four-two-minus

ANSWER: ALL

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TOSS-UP

14) Energy – *Short Answer*   Scientists in the Limmer Group at UC Berkeley are investigating twisted bilayer graphene to better understand its electronic structure. Twisted bilayer graphene consists of two graphene sheets stacked on each other at a small twist angle, which results in what large-scale geometric structure?

ANSWER: MOIRÉ SUPERLATTICE (ACCEPT: MOIRÉ PATTERN)

BONUS

14) Energy – *Multiple Choice*   Scientists in the Stanley Lab at UC Berkeley are researching the mechanisms behind how tuberculosis evades macrophage defenses. Which of the following is a downstream effect of IFN-gamma signaling in macrophages that enhances bacterial clearance during TB infection?

W) Downregulation of phagolysosomal fusion and acidification
X) Inhibition of reactive oxygen species production
Y) Upregulation of phagocytic activity and intracellular killing
Z) Suppression of cytokine and chemokine production

ANSWER: Y) UPREGULATION OF PHAGOCYTIC ACTIVITY AND INTRACELLULAR KILLING

TOSS-UP

15) Earth and Space – *Multiple Choice*   The term El Niño is used to describe periods when strong warm undercurrents replace colder offshore currents. Which of the following is NOT an effect of El Niño?

W) Fish dying due to upwelling blocking colder, nutrient rich water
X) Inland areas receiving an abnormal amount of rain
Y) Barometric pressure decreasing over much of the Southeastern Pacific
Z) Very dry conditions along the west coast of South America

ANSWER: Z) VERY DRY CONDITIONS ALONG THE WEST COAST OF SOUTH AMERICA

BONUS

15) Earth and Space – *Short Answer*   What is the name given to the Kuiper belt objects that are in a 3:2 resonance with Neptune?

ANSWER: PLUTINOS

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TOSS-UP

16) Biology – *Short Answer*   A cell with a diploid number of 6 could produce gametes with how many different combinations of maternal and paternal chromosomes?

ANSWER: 8

BONUS

16) Biology – *Multiple Choice*   Which of the following is true regarding the antibodies and the immune system?

W) Antibodies are produced by B cells and recognize antigens through their T cell receptors
X) Antibodies can destroy cell membranes through membrane attack complex formation
Y) The constant region of an antibody determines its antigen specificity
Z) The heavy chain determines the class or isotype of the antibody

ANSWER: Z) THE HEAVY CHAIN DETERMINES THE CLASS OR ISOTYPE OF THE ANTIBODY

TOSS-UP

17) Physics – *Short Answer*   If the dispersion relation of a wave is given by the function omega of k equals the sine of k, then what is the phase velocity at $k = \pi/2$?

ANSWER: $2/\pi$

BONUS

17) Physics – *Short Answer*   Identify all of the following symmetries that are obeyed by the decay processes of neutral kaons: 1) C-symmetry; 2) CP-symmetry; 3) CPT-symmetry.

ANSWER: 3 ONLY

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TOSS-UP

18) Math – *Short Answer*   In $\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$ notation, what is the gradient of the expression $2xy + z^3$?

ANSWER: $2y\boldsymbol{i} + 2x\boldsymbol{j} + 3z^2\boldsymbol{k}$

BONUS

18) Math – *Short Answer*   After rolling 4 dice and adding their top values, what is the probability of obtaining a sum of 10?

ANSWER: 5/81

TOSS-UP

19) Earth and Space – *Short Answer*   Identify all of the following three statements that are assumptions of the single-cell model of atmospheric circulation: 1) The surface of the Earth is uniformly covered with water; 2) The sun is always directly over the equator; 3) Earth does not rotate.

ANSWER: ALL

BONUS

19) Earth and Space – *Short Answer*   A band of rock containing a large quantity of iridium can be found at the boundary between what two geologic periods?

ANSWER: CRETACEOUS AND TERTIARY (ACCEPT: CRETACEOUS AND PALEOGENE)

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TOSS-UP

20) Physics – *Short Answer*   A uniform, infinite sheet of negative charge is oriented along the *x-z* plane. Giving your answer in i, j, k notation, in what direction is the electric field vector facing at the point (2, 3, 1)?

ANSWER: $-j$ (DO NOT ACCEPT: j; $+j$)

BONUS

20) Physics – *Short Answer*   In most metals, electrons are the charge carriers. If the original conductivity of a metal is K and the charge carries are replaced by quasiparticles with one third the magnitude of the elementary charge, what is the new conductivity of the metal in terms of K?

ANSWER: $K/9$

TOSS-UP

21) Biology – *Short Answer*   In the final step of the Citric acid cycle, malate is oxidized by NAD^+ in the presence of malate dehydrogenase to regenerate what molecule?

ANSWER: OXALOACETATE

BONUS

21) Biology – *Short Answer*   Identify all of the following three statements that are true regarding epithelial tissue: 1) Simple columnar epithelium lines the intestines, secreting digestive juices and absorbing nutrients; 2) Stratified squamous epithelium lines blood vessels and the air sacs of the lungs; 3) Cuboidal epithelium makes up the epithelium of kidney tubules and thyroid glands.

ANSWER: 1 AND 3

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TOSS-UP

22) Chemistry – *Multiple Choice*   Which of the following statements accurately describes the reactivity of pyridine derivatives compared to benzene derivatives?

W) Better at both electrophilic and nucleophilic aromatic substitution
X) Better at electrophilic but worse at nucleophilic aromatic substitution
Y) Better at nucleophilic but worse at electrophilic aromatic substitution
Z) Worse at both electrophilic and nucleophilic aromatic substitution

ANSWER: Y) BETTER AT NUCLEOPHILIC BUT WORSE AT ELECTROPHILIC AROMATIC SUBSTITUTION

BONUS

22) Chemistry – *Short Answer*   In the Berry pseudorotation of PF_5, what is the molecular geometry of the transition state?

ANSWER: SQUARE PYRAMIDAL

TOSS-UP

23) Math – *Short Answer*   For a function to be continuous at a certain point, identify all of the following three statements that must be true: 1) The point is defined; 2) The limit at the point exists; 3) The value of the point and the limit are equal.

ANSWER: ALL

BONUS

23) Math – *Short Answer*   If the line segment of $y = 3x$ from 0 to 5 is rotated about the *x*-axis, what are the volume and lateral surface area, respectively, of the solid formed by this revolution?

ANSWER: 375π AND 75π ROOT 10