

BSB ROUND 12

TOSS-UP

1) Physics – *Multiple Choice* Which of the following systems produces an electric field with $1/r^3$ dependence, where r is the distance from the center of the system?

- W) Point charge
- X) Electric dipole
- Y) Electric quadrupole
- Z) Electric octupole

ANSWER: X) ELECTRIC DIPOLE

BONUS

1) Physics – *Short Answer* In solid-state physics, energy and what other quantity must be conserved when two phonons scatter in a crystal lattice?

ANSWER: CRYSTAL MOMENTUM (DO NOT ACCEPT: MOMENTUM)

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### TOSS-UP

2) Earth and Space – *Short Answer* Stream channels with nearly vertical walls and flat bottoms are common characteristics of what geologic features that are found in semi-arid regions?

ANSWER: ARROYOS (ACCEPT: DRY WASH)

### BONUS

2) Earth and Space – *Multiple Choice* Which of the following statements regarding porosity and permeability is true?

- W) Aquitards are highly impermeable regions within the Earth
- X) Porosity is a measure of the ease with which a fluid can move through a rock
- Y) There is a positive relationship between the compaction level of rocks and their permeability
- Z) Fine grained sedimentary rocks such as clay have poor permeability

ANSWER: W) AQUITARDS ARE HIGHLY IMPERMEABLE REGIONS WITHIN THE EARTH

### TOSS-UP

3) Chemistry – *Multiple Choice* Which of the following molecules would react most favorably with nitroethene in a thermal pericyclic reaction?

- W) 1-methoxybutadiene
- X) 1-chlorobutadiene
- Y) 1-nitrobutadiene
- Z) 1-cyanobutadiene

ANSWER: W) 1-METHOXYBUTADIENE

### BONUS

3) Chemistry – *Short Answer* Identify all of the following three statements that are true regarding the *trans* effect: 1) It is most commonly observed in octahedral complexes; 2) Ammonia is a stronger *trans* director than chloride; 3) It is a purely thermodynamic phenomenon.

ANSWER: 2 ONLY

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TOSS-UP

4) Biology – *Multiple Choice* Which of the following statements is true regarding embryonic development?

- W) The blastula is formed during the gastrulation stage of development
- X) The blastocoel is a cavity that forms within the archenteron during gastrulation
- Y) The archenteron gives rise to the ectodermal layer of the embryo
- Z) Gastrulation involves the formation of the blastocoel

ANSWER: X) THE BLASTOCOEL IS A CAVITY THAT FORMS WITHIN THE ARCHENTERON DURING GASTRULATION

BONUS

4) Biology – *Multiple Choice* Which of the following statements is true regarding oncogenes?

- W) Upregulation of oncogenes can lead to cancer
- X) The p53 gene is a proto-oncogene
- Y) Many oncoproteins suppress transcription
- Z) Proto-oncogenes are only found in cancer cells

ANSWER: W) UPREGULATION OF ONCOGENES CAN LEAD TO CANCER

TOSS-UP

5) Energy – *Short Answer* Scientists in the Hartwig Group at UC Berkeley are developing organometallic catalysts to perform cross-coupling reactions. One of the structural motifs [*mo-TEEFS*] in their catalysts is ferrocene, which, indicating proper charge, features an iron atom in what oxidation state?

ANSWER: +2 (DO NOT ACCEPT: 2; -2)

BONUS

5) Energy – *Multiple Choice* Scientists in the Park Lab at UC Berkeley are studying the molecular mechanisms of protein translocation across membranes and related quality control pathways using biochemical and structural approaches. Which of the following is a required component for protein translocation into the endoplasmic reticulum?

- W) Signal peptidase
- X) Signal recognition particle
- Y) Signal sequence
- Z) Chaperones

ANSWER: X) SIGNAL RECOGNITION PARTICLE

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### TOSS-UP

6) Math – *Short Answer* What is the smallest 3-digit positive integer such that it has a remainder of eight when divided by nine, remainder of two when divided by five, and remainder of one when divided by 4?

ANSWER: 197

### BONUS

6) Math – *Multiple Choice* To the nearest tenth, what is the radius of the largest circle that fits in the gap created by pressing three rigid circles of radius 1 against each other?

- W) 0.2
- X) 0.3
- Y) 0.4
- Z) 0.5

ANSWER: W) 0.2

### TOSS-UP

7) Energy – *Multiple Choice* Researchers in the Reimer Group at UC Berkeley are utilizing metal-organic frameworks to adsorb ammonia. However, many such frameworks “collapse”, or lose their crystallinity, after ammonia adsorption due to strong coordination between ammonia and the metal ion. Which of the following metal ions would create the least stable metal-organic framework in ammonia?

- W) Aluminum
- X) Copper
- Y) Indium
- Z) Gold

ANSWER: X) COPPER

### BONUS

7) Energy – *Multiple Choice* Scientists at Lawrence Berkeley National Labs have created a new solid electrolyte for solid-state batteries using multiple different transition metals that exhibits a much higher ionic conductivity than single-metal electrolytes. What is one DISADVANTAGE of having battery electrolytes with higher ionic conductivity?

- W) Lower coulombic efficiency
- X) Higher leakage current
- Y) Slower charging rate
- Z) Lower battery energy density

ANSWER: X) HIGHER LEAKAGE CURRENT

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TOSS-UP

8) Biology – *Short Answer* If a child has type-O blood and her mother has type-A blood, identify all of the following three blood types the father can have: 1) A; 2) B; 3) AB.

ANSWER: 1 AND 2

BONUS

8) Biology – *Short Answer* Sanger sequencing has largely been replaced by what method, in which researchers can sequence millions of DNA fragments simultaneously?

ANSWER: NEXT-GEN SEQUENCING (ACCEPT: NGS)

TOSS-UP

9) Chemistry – *Short Answer* What is the major product of the solvolysis of tert-butylbromide in water?

ANSWER: TERT-BUTANOL

BONUS

9) Chemistry – *Short Answer* How many stereoisomers exist of the coordination compound with formula $\text{Pt-NH}_3\text{-four-Cl-Br-two-plus}$?

ANSWER: 2

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### TOSS-UP

10) Physics – *Multiple Choice* In the early 19th century, scientists believed that the heat capacity of a mole of any solid was equal to 3 times the ideal gas constant. Einstein provided a correction to this model by considering each atom in a solid to be which of the following?

- W) Simple harmonic oscillator
- X) Damped harmonic oscillator
- Y) Anharmonic oscillator
- Z) Quantum harmonic oscillator

ANSWER: Z) QUANTUM HARMONIC OSCILLATOR

### BONUS

10) Physics – *Short Answer* What is the y-coordinate of the center of mass of a uniform equilateral triangle in the first quadrant with two corners at (0, 0) and (1, 0)?

ANSWER: SQUARE ROOT OF 3 OVER 6

### TOSS-UP

11) Earth and Space – *Multiple Choice* Which of the following terms is the process by which water dissolves soluble inorganic soil components and carries them to deeper areas, thereby depleting upper zones?

- W) Eluviation
- X) Liquefaction
- Y) Secondary enrichment
- Z) Leaching

ANSWER: Z) LEACHING

### BONUS

11) Earth and Space – *Short Answer* What is the name given to tidal waves that surge up rivers from narrow estuaries?

ANSWER: TIDAL BORES

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TOSS-UP

12) Math – *Short Answer* What is the sum of the digits of the square of the number 111?

ANSWER: 9

BONUS

12) Math – *Short Answer* Buckminsterfullerene is a naturally occurring 3D structure that has 32 faces consisting of pentagons and hexagons, with 5 hexagons for every 3 pentagons. How many hexagons, pentagons, and vertices, respectively, make up this shape?

ANSWER: 20, 12, 60 (ACCEPT: 20 HEXAGONS, 12 PENTAGONS, 60 VERTICES)

TOSS-UP

13) Energy – *Short Answer* Scientists at UC Berkeley have been in collaboration with UCSF researchers to develop novel anti-tumor agents. One of their starting points has been improving a type of chemotherapy involving cisplatin, which is a metal coordination compound that destroys cancer DNA by binding to what element found on purine rings?

ANSWER: NITROGEN

BONUS

13) Energy – *Short Answer* Researchers in the Yang Group at UC Berkeley have been using Raman spectroscopy to understand surface reaction intermediates on transition metal electrodes. Rank the following three Raman peaks in terms of increasing intensity: 1) Stokes; 2) Anti-Stokes; 3) Rayleigh.

ANSWER: 2, 1, 3

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### TOSS-UP

14) Earth and Space – *Multiple Choice* Which of the following is closest to the length of the sunspot cycle?

- W) 1 year
- X) 6 years
- Y) 11 years
- Z) 16 years

ANSWER: Y) 11 YEARS

### BONUS

14) Earth and Space – *Multiple Choice* Plate tectonics play an active role in shaping the surface of the Earth. Given that present-day plate movements persist, which of the following changes is least likely to occur 50 million years from now?

- W) The Mediterranean Sea will close due to the collision of Africa and Europe
- X) Australia will be near the equator
- Y) The Atlantic oceans will continue to grow
- Z) North and South America will collide

ANSWER: Z) NORTH AND SOUTH AMERICA WILL COLLIDE

### TOSS-UP

15) Chemistry – *Short Answer* To the nearest tenth, what is the  $R_F$  value for a sample that traveled 1.5 centimeters, given the solvent traveled 4.5 centimeters?

ANSWER: 0.3

### BONUS

15) Chemistry – *Short Answer* Identify all of the following three quantum numbers that are important in determining the angular part of a hydrogen atom wavefunction: 1) Principal quantum number; 2) Angular momentum quantum number; 3) Magnetic quantum number.

ANSWER: 2 AND 3

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TOSS-UP

16) Biology – *Short Answer* Gastric protein digestion takes place when parietal cells facilitate the formation of hydrochloric acid, which combines with what zymogen secreted by chief cells, yielding an active enzyme?

ANSWER: PEPSINOGEN

BONUS

16) Biology – *Short Answer* The overuse of benzocaine, a common topical anesthetic, can cause hypoxia by oxidizing the iron in hemoglobin. What is the name of this altered form of hemoglobin?

ANSWER: METHEMOGLOBIN

TOSS-UP

17) Math – *Short Answer* What is the sum from $n = 1$ to infinity of the expression 1 over n^4 ?

ANSWER: $\pi^4/90$

BONUS

17) Math – *Short Answer* In a standard deck of 52 cards, what is the probability of pulling a face card and then another face card without replacement?

ANSWER: 11/221

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**TOSS-UP**

18) Physics – *Short Answer* A 5-kilogram particle moves along the  $x$ -axis according to the function  $x(t) = t^3 + 5t^2 + 3t + 2$ , where  $x$  is in meters and  $t$  is in seconds. In newtons, what is the net force acting on the particle at time  $t = 3$  seconds?

ANSWER: 140

**BONUS**

18) Physics – *Short Answer* If a ray of polarized visible light is shone onto a sheet of glass with a dielectric constant of 3 and zero magnetic susceptibility such that the angle of incidence is 60 degrees, what will the observed angle of refraction be in degrees?

ANSWER: 30

### TOSS-UP

19) Biology – *Multiple Choice* Which of the following is the name of the general class of chemical reaction that converts pyruvate to acetaldehyde, the precursor of ethanol in alcohol fermentation?

- W) Decarbonylation [*dee-car-BON-ill-a-shun*]
- X) Decarboxylation [*dee-car-BOX-ill-a-shun*]
- Y) Acetylation [*uh-SET-ill-a-shun*]
- Z) Condensation

ANSWER: X) DECARBOXYLATION

### BONUS

19) Biology – *Short Answer* Given the following recombination frequencies, give the correct order of the genes on the chromosome: A to B is 8 map units, A to C is 28 map units, A to D is 25 map units, B to C is 20 map units, and B to D is 33 map units.

ANSWER: D, A, B, C (ACCEPT: C, B, A, D)

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TOSS-UP

20) Chemistry – *Short Answer* How many allylic hydrogens can be found in one molecule of cyclohexene?

ANSWER: FOUR

BONUS

20) Chemistry – *Multiple Choice* The reaction $A \rightarrow B$ proceeds via two elementary steps: $A \rightarrow I$ then $I \rightarrow B$, where I is an intermediate. The two steps have rate constants of 2 inverse seconds and 4 inverse seconds, respectively. Which of the following is closest to the time in seconds at which the maximum concentration of the intermediate I is reached?

- W) 0.1
- X) 0.2
- Y) 0.3
- Z) 0.4

ANSWER: Y) 0.3

TOSS-UP

21) Math – *Short Answer* In base 4, what is the smallest prime number that is larger than 123 base 4?

ANSWER: 131

BONUS

21) Math – *Short Answer* What is the real eigenvalue of the following 3-by-3 matrix: top row (1, 2, 3), middle row (1, -1, 4), and bottom row (-2, -4, 1)?

ANSWER: -1

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### TOSS-UP

22) Earth and Space – *Multiple Choice* The angular distance between a planet and the Sun, as viewed from the Earth, is called which of the following?

- W) Angle of inclination
- X) Elongation
- Y) Conjunction
- Z) Opposition

ANSWER: X) ELONGATION

### BONUS

22) Earth and Space – *Multiple Choice* Which of the following is a type of glacier that forms when a valley glacier spreads out into a low, flat area?

- W) Piedmont glacier
- X) Alpine glacier
- Y) Outlet glacier
- Z) Tidewater glacier

ANSWER: W) PIEDMONT GLACIER

### TOSS-UP

23) Physics – *Short Answer* A particle with an energy of 1 electron volt is placed in a 1-dimensional box with potential barriers of 10 electron volts each. What phenomenon predicts that the wavefunction of the particle will exist beyond the walls of the box?

ANSWER: QUANTUM TUNNELING

### BONUS

23) Physics – *Short Answer* In semiconductors such as silicon, it is difficult for light to promote electrons across indirect band gaps. These processes can only occur if the absorption of a photon is coupled with the emission of what particles?

ANSWER: PHONONS (DO NOT ACCEPT: PHOTONS)