SBL FALL QUARTERFINALS
4:47 AM

TOSS-UP

1) Chemistry - *Short Answer* In a hypothetical reaction, one molecule of A decomposes into two molecules of B in a zeroth order reaction. Identify all of the following 3 statements that are true of this reaction: 1) The half life of the reaction increases over time; 2) Plotting concentration of molecule A over time yields a straight line; 3) The reciprocal of the reaction rate increases linearly with respect to temperature.

ANSWER: 2 ONLY [CT]

BONUS

1) Chemistry - *Short Answer* Order the following three compounds by increasing stability of their hydrates: 1) Methyl ethyl ketone; 2) Hexafluoroacetone; 3) Acetaldehyde .

ANSWER: 1, 3, 2 [YL]

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TOSS-UP

2) Biology – *Short Answer* [9] The lack of orexins ***[or-REX-ins]*** in the VLPO secretion centers of the brain is implicated in which disorder?

ANSWER: NARCOLEPSY [Animal Physiology - Nervous Systems, SF]

BONUS

2) Biology – *Short Answer* [7] Identify all of the following three techniques that primarily serve to model protein secondary structure: 1) Edman degradation; 2) De-Novo synthesis using primer; 3) Circular dichroism spectroscopy.

ANSWER: 3 ONLY [Biochemistry - Protein Structure, SF]
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TOSS-UP

3) Earth and Space – *Short Answer* [7] What term is given to specific groups of asteroids that follow the same eccentricity and inclination in their orbits but do not usually collide?

ANSWER: HIRAYAMA FAMILIES [Astronomy - Solar System, SF]

BONUS

4) Earth and Space – *Short Answer* [7] Identify all of the following three statements that are true regarding meteorites: 1) Iron meteorites cooled slowly after formation; 2) Chondrules ***[KON-drules]*** within Chondrite meteorites cooled slowly; 3) Calcium-aluminum rich inclusions crystallize at high temperatures.

ANSWER: 1 AND 3 [Astronomy - Solar System, SF]

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TOSS-UP

4) Math – *Multiple Choice* [7] Ryan is constructing a basis for R cubed using the vectors 6i + 7j and 9i + 7j. Which of the following vectors could NOT make a valid basis with the previous two vectors?

W) 3i + 3j + 3k
X) 5i + 9j
Y) i – k
Z) 4j + 3k

ANSWER: X) 5i + 9j [Alg - Vec, CT]

BONUS

4) Math – *Short Answer* [7] Alice and Bob play a game with *n* marbles, with Alice going first. On every player's turn, they can remove either 1 or 2 marbles, and whoever takes the last marble wins. Assuming optimal play, for how many values of *n* between 1 and 2020 inclusive does Bob win?

ANSWER: 673 [Com - Game, CT]
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TOSS-UP

5) Energy – *Short Answer* [?] Researchers at Pacific Northwest National Lab have been studying the physiological effects of ketone bodies in the bloodstream. When ketogenesis occurs in the liver, what other biochemical process would you also expect to be occurring in liver cells that generate glucose?

ANSWER: GLUCONEOGENESIS [DJ]

BONUS

5) Energy – *Short Answer* [5] Scientists at Pacific National Lab have studied the propagation of uranium compounds in the environment. A common oxycation of uranium, the uranyl ion, has a chemical formula of UO_2^{2+}. What is the bond order of the uranium-oxygen bond in the uranyl cation?

ANSWER: 3 [Chem, YL]

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TOSS-UP

6) Physics – *Multiple Choice* [7] A particle with its spin in the same direction as its motion is said to be which of the following?
W) Spin-up
X) Spin-down
Y) Left-handed
Z) Right-handed

ANSWER: Z) RIGHT-HANDED [Particle, DK]

BONUS

6) Physics – *Short Answer* [6] A 2 microcoulomb charge is placed 3 centimeters away from an infinite conducting sheet. To the nearest whole number, how many newtons of force does it experience?

ANSWER: 10 [Electrostatics, DK]
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TOSS-UP

7) Earth and Space – *Short Answer* [8] The Penrose process proposes the extraction of energy from a rotating black hole in what region where any object is dragged by a rotating spacetime?

ANSWER: ERGOSPHERE [Astronomy - Other, SF]

BONUS

7) Earth and Space – *Short Answer* [8] Identify all of the following three statements that are true of the Venusian ***[veh-NOO-shun]*** surface and atmosphere: 1) There exists both shield and composite volcanoes; 2) There exists a high protium to deuterium ratio due to the lack of an ozone layer; 3) Venus possesses a weak, but effective magnetic field.

ANSWER: NONE [Astronomy - Solar System, SF]

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TOSS-UP

8) Biology – *Short Answer* Larger metabolites such as flavonoids and anthocyanins are often transported into the central vacuole without the dependence of a concentration gradient but rather with ATP. What general group of transporters transport these large molecules?

ANSWER: ABC TRANSPORTER (ACCEPT: ATP BINDING CASSETTE TRANSPORTER) [SF]

BONUS

8) Biology – *Short Answer* Nucleotide analogs have provided great insight into the molecular structure and function of ATP-binding proteins and nucleotide-binding proteins in general. Which of the following statements is NOT true regarding these nucleotide analogs?

W) MgF_3^- can be used to mimic the transition state for a phosphoryl transfer reaction.
X) $MgADP{\cdot}VO_4$ can be used to trap the metaphosphate transition state for phosphoryl transfer.
Y) ATPS has proven to be one of the best analogs for ATP, but it is slowly hydrolyzed.
Z) AMPPNP is often used to mimic ATP in the active site of an enzyme, but generally binds less tightly than ATP.

ANSWER: X) $MGADP{\cdot}VO_4$ CAN BE USED TO TRAP THE METAPHOSPHATE TRANSITION STATE FOR PHOSPHORYL TRANSFER. [DJ]
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TOSS-UP

9) Energy – *Short Answer* Scientists at Brookhaven National Lab are studying the synthetic applications of the Staudinger amine synthesis that goes through an azide intermediate. What molecule acts as the leaving group in order to generate the amine?

ANSWER: TRIPHENYLPHOSPHINE OXIDE [DJ]

BONUS

9) Energy – *Short Answer* Researchers at Brookhaven National Lab have been measuring the rates of diffusion through cell membranes to aid in the development of drug delivery. Which of the following scenarios best increases the fluidity of a cellular membrane?

W) An increase in temperature
X) A decrease in the length of the alkyl chains in the lipid bilayer
Y) An increase in the percentage of unsaturated fatty acids in the lipid bilayer
Z) An increase in the rate of transverse diffusion of lipids

ANSWER: Y) AN INCREASE IN THE PERCENTAGE OF UNSATURATED FATTY ACIDS IN THE LIPID BILAYER [DJ]

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TOSS-UP

10) Math – *Short Answer* [6] A tree has 2020 vertices. What is the maximum number of edges that it could have?

ANSWER: 2019 [Com - Graph, CT]

BONUS

10) Math – *Short Answer* [7] What is the minimum side length of an equilateral triangle that can fit three disjoint unit circles in its interior?

ANSWER: 2 PLUS 2 ROOT 3 [Geo - Tri, CT]
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TOSS-UP

11) Chemistry – *Short Answer* What is the term given to the region produced in infrared spectroscopy in which compounds create characteristic patterns that can be used to identify them?

ANSWER: FINGERPRINT REGION [CK]

BONUS

11) Chemistry – *Short Answer* Identify all of the following 3 statements that are generally true of high-spin complexes: 1) They contain strong field ligands; 2) They are paramagnetic; 3) They have a large crystal field splitting energy.

ANSWER: 2 ONLY

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TOSS-UP

12) Physics – *Short Answer* [6] Two metal plates are arranged to form a parallel-plate capacitor. A third identical plate is inserted halfway in between the other two. By what factor is the capacitance of the device multiplied?

ANSWER: 1 [Electrostatics, DK]

BONUS

12) Physics – *Short Answer* [7] Identify all of the following three statements that are true of the weak interaction: 1) It acts only on charged particles; 2) It conserves lepton number; 3) It mediates the decay of the top quark.

ANSWER: 2 AND 3 [Particle, DK]
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TOSS-UP

13) Biology – *Multiple Choice* [4] In a bottom-up model of a hypothetical ecosystem, sharks eat humans, humans eat chickens, and chickens eat mustard plants. If you wished to increase the chicken population, which of the following would have the largest impact?

W) Add sharks
X) Remove humans
Y) Add mustard plants
Z) Remove both humans and mustard plants

ANSWER: Y) ADD MUSTARD PLANTS [Ecology - Ecosystem, SF]

BONUS

13) Biology – *Short Answer* Identify all of the following three statements regarding hemoglobin that are true: 1) It has an increased affinity for oxygen in the R state; 2) It possesses a Hill coefficient of more than one; 3) Fetal hemoglobin has an increased affinity for 2,3 BPG when compared to adult hemoglobin.

ANSWER: ALL OF THEM [Biochemistry - Proteins, SF]

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TOSS-UP

14) Math – *Short Answer* [7] What is the divergence of the vector field $f(x, y, z) = xy\,\mathbf{i} + yz\,\mathbf{j} + xz\,\mathbf{k}$?

ANSWER: $x + y + z$ [Calc - Vec, CT]

BONUS

14) Math – *Short Answer* [7] What is the sum of the two largest prime factors of 123,876?

ANSWER: 68 [NT - Fac, CT]
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TOSS-UP

15) Earth and Space – *Multiple Choice* [7] Galactic fountains are features that spread relatively hot, metal-enriched gas high above the disk of a spiral galaxy. Which of the following best describes how most galactic fountains form?

W) Intense stellar winds and supernovae
X) Tidal forces from a central supermassive black hole
Y) Relativistic jets from a neutron star
Z) Tidal forces from orbiting dwarf galaxies

ANSWER: W) INTENSE STELLAR WINDS AND SUPERNOVAE [Astronomy - Other, YL]

BONUS

15) Earth and Space – *Short Answer* [8] Identify all of the following three characteristics that would be expected for subtropical gyre circulation in the Northern Hemisphere: 1) Downwelling at the center; 2) Counterclockwise flow; 3) Stronger eastern boundary currents and weaker western boundary currents.

ANSWER: 1 ONLY [Oceanography, YL]

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TOSS-UP

16) Physics – *Multiple Choice* [5] Which of the following pairs of statements are true of the tension in a hanging chain?

W) Both vertical and horizontal tension are constant
X) Vertical tension is constant, while horizontal tension is highest at the center
Y) Vertical tension is highest at the center, while horizontal tension is constant
Z) Both vertical and horizontal tension are highest at the center

ANSWER: Y) Vertical tension is highest at the center, horizontal tension is constant [Mech, DK]

BONUS

16) Physics – *Short Answer* Two identical blocks, A and B, each have an edge length of 8 cm and a density of 100 kg/m^3. Block A is placed in a container with water of density 1000 kg/m^3, while Block B is placed in an identical container with ethanol of density 800 kg/m^3. In cubic cm, how much more of Block B is submerged in the liquid than Block A?

ANSWER: 12.8 (ACCEPT: 64/5) [CK]
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TOSS-UP

17) Energy – *Short Answer* Researchers at Los Alamos National Lab are studying the Earth's interior. Which of the following statements is false about their research?

W) The phase change between the spinel and perovskite structure occurs within the D'' ***[D double prime]*** layer
X) Positive velocity anomalies in seismic tomography are associated with cooler rock
Y) Phase changes in olivine cause discontinuities in seismic wave velocities
Z) Some mantle minerals may store water within their structure

ANSWER:W) THE PHASE CHANGE BETWEEN THE SPINEL AND PEROVSKITE STRUCTURE OCCURS WITHIN THE D'' LAYER [YL]

BONUS

17) Energy – *Multiple Choice* Researchers at Oak Ridge National Lab are investigating specific crystal defects. Which of the following best describes a Frenkel defect?

W) A crystal lattice changes direction, creating a grain boundary
X) A particle changes lattice site, creating a vacancy defect and an interstitial defect
Y) A combination of an edge dislocation and a screw dislocation
Z) A switch between two atoms of different types in an ordered crystal lattice.

ANSWER: X) A PARTICLE CHANGES LATTICE SITE, CREATING A VACANCY DEFECT AND AN INTERSTITIAL DEFECT [TZ]

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TOSS-UP

18) Chemistry – *Multiple Choice* Which of the following would NOT be a way to efficiently generate a ketone?
W) Reaction of a nitrile with a grignard, then protonation by a weak acid
X) Reaction of a Weinreb amide with a grignard, then protonation by a weak acid
Y) Reaction of an ester with a grignard, then protonation by a weak acid.
Z) Reaction of an acyl chloride with a dialkylcuprate, then protonation by a weak acid

ANSWER: Y) REACTION OF AN ESTER WITH A GRIGNARD, THEN PROTONATION BY A WEAK ACID [DJ]

BONUS

18) Chemistry – *Short Answer* Identify all of the following 3 catalysts that contain a transition metal carbene complex: 1) Wilkinson; 2) Schrock; 3)Grubbs
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ANSWER: 2 AND 3 [DJ]

TOSS-UP

19) Biology – *Short Answer* What element, a mammalian micronutrient, is a common cofactor for thyroid peroxidase enzymes?

ANSWER: SELENIUM [RB]

BONUS

19) Biology – *Short Answer* [7] Which disaccharide is synthesized by many invertebrates to prevent their bodily fluids from freezing when subjected to cold and dry conditions?

ANSWER: TREHALOSE [Animal Physiology - Misc, SF]

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TOSS-UP

20) Math – *Short Answer* [7] How many terms are in the binomial expansion of open parentheses $x^2 + xy + y^2$ close parentheses to the 7th power?

ANSWER: 15 [Alg - Poly, CT]

BONUS

20) Math – *Short Answer* [8] A cone has a height of 8 and a radius of 6. A frustum is formed by making a cut parallel to the base and removing the cone-shaped section above it. If the height of the frustum is 5, what is the radius of the largest sphere that can be inscribed in the frustum?

ANSWER: 2.5 [Geo - 3D, CT]
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TOSS-UP

21) Earth and Space – *Short Answer* [9] Identify all of the following three mechanisms or phenomena that contribute to ocean mixing: 1) Cyclones; 2) Internal tidal waves; 3) Vertical eddy diffusion.

ANSWER: ALL [Oceanography, YL]

BONUS

21) Earth and Space – *Multiple Choice* [7] Which of the following statements regarding the speed of sound in seawater is not true?

W) There exists a depth at which the speed of sound in seawater reaches a minimum
X) The speed of sound in seawater increases as temperature increases
Y) For a given temperature, the speed of sound in seawater is always greater than that of freshwater
Z) The speed of sound in seawater can be expressed as a bivariate function of temperature and salinity

ANSWER: Z) THE SPEED OF SOUND IN SEAWATER CAN BE EXPRESSED AS A BIVARIATE FUNCTION OF TEMPERATURE AND SALINITY [Oceanography, YL]

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TOSS-UP

22) Chemistry - *Multiple Choice* Which of the following best describes the metal-ligand bond in nickel tetracarbonyl?

W) Sigma electrons are donated from ligand to metal, pi electrons are donated from metal to ligand
X) Sigma electrons are donated from metal to ligand, pi electrons are donated from ligand to metal
Y) Both sigma and pi electrons are donated from metal to ligand
Z) Both sigma and pi electrons are donated from ligand to metal

ANSWER: W) SIGMA ELECTRONS ARE DONATED FROM LIGAND TO METAL, PI ELECTRONS ARE DONATED FROM METAL TO LIGAND [YL]

BONUS

22) Chemistry – *Short Answer* Identify all of the following three properties that are greater for the hydrosulfide anion than the hydroxide anion: 1) Nucleophilicity; 2) pKa; 3) Bond length.
ANSWER: 1, 3
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TOSS-UP

23) Physics – *Multiple Choice* [5] Soap bubbles appear to have iridescent, rainbow-colored appearances. This occurs due to the varying effects of what optical phenomenon at different wavelengths?

W) Emission
X) Absorption
Y) Refraction
Z) Interference

ANSWER: Z) INTERFERENCE [Optics, DK]

BONUS

Physics – *Short Answer* [5] A 1 kilogram particle with charge 2 coulombs is placed into an electric field with potential $V(x) = 3x + 4$ in volts. If it begins at rest at the origin, how many meters has it traveled after 5 seconds?

ANSWER: 75 [E&M, DK]