SBL FALL SEMIFINALS

Chem and physics and energy: there's some things that need to be cleared and/or redone

TOSS-UP

1) Math – *Short Answer* [8] Compute the Dirac delta function of x evaluated at each of the following 3 x values: 1) $x = -1$, 2) $x = 0$, 3) $x = 1$.

ANSWER: 0, INFINITY (ACCEPT: UNDEFINED), 0 [Alg - Func, CT]

BONUS

1) Math – *Short Answer* [7] In right triangle ABC, leg AB is 3 and leg BC is 4. Let X be the incenter of triangle ABC. What is the length of segment AX?

ANSWER: ROOT 5 [Geo - Tri, CT]

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TOSS-UP

2) Earth and Space – *Short Answer* [7] Identify all of the following three statements that are true regarding the Intertropical Convergence Zone, or ITCZ: 1) Its average position is usually south of the equator; 2) It is pushed away from Asia in boreal winter months; 3) The vertical extent of the ITCZ is generally bounded by the tropopause.

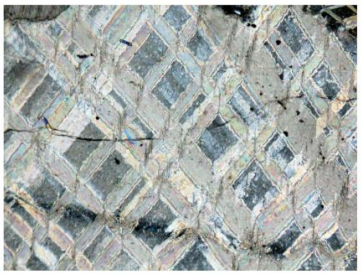
ANSWER: 2 AND 3 [Meteorology, YL]

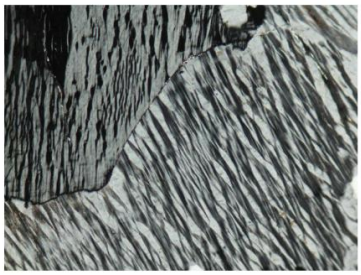
VISUAL BONUS

2) Earth and Space – *Multiple Choice* [9] Jay the geochemist is unsuccessfully trying to identify zircon crystals in his thin sections. Shown in the figure are four thin sections in plane polarized light. Identify the thin section that contains zircon.
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W) 

X) 

Y) 

Z) 

ANSWER: W [Geology - Mineralogy, YL]

TOSS-UP

3) Physics – *Short Answer* The torque on an object in a uniform magnetic field is the cross product of the magnetic field and what other quantity?

ANSWER: MAGNETIC DIPOLE MOMENT (ACCEPT: MAGNETIC MOMENT) [SS]

BONUS

3) Physics – *Short Answer* Photon A is emitted from an electron in a hydrogen atom dropping from the $n = 3$ level to the $n = 1$ level. Photon B is emitted from an electron in a hydrogen atom dropping from the $n = 3$ level to the $n = 2$ level. What is the ratio of the frequency of photons A to the frequency of photon B?

ANSWER: 32/27

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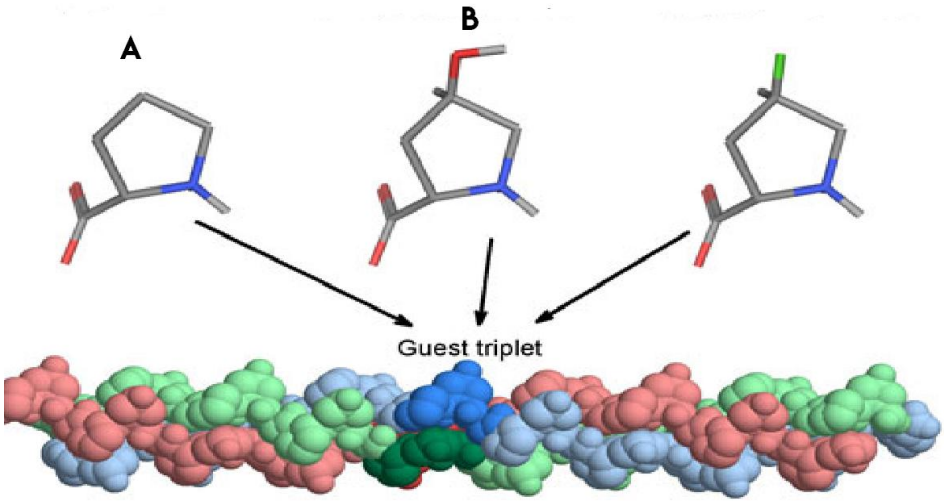
TOSS-UP

4) Biology – *Short Answer* [1] In vertebrate gap junctions, which transmembrane proteins are responsible for forming the channels?

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

VISUAL BONUS

4) Biology – *Short Answer* [8] Shown in the image is a specific protein that adopts a triple helix as a super secondary structure and requires certain cofactors for the crucial hydroxylation of amino acid residues within the protein. Answer the following two questions concerning this protein: 1) What protein is depicted?; 2) What are the names of the amino acid labeled A, and the hydroxylated amino acid labeled B respectively?
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ANSWER: 1) COLLAGEN; 2) A IS PROLINE AND B IS 4-HYDROXYPROLINE (ACCEPT: HYDROXYPROLINE) [Biochemistry - Proteins, SF]

TOSS-UP

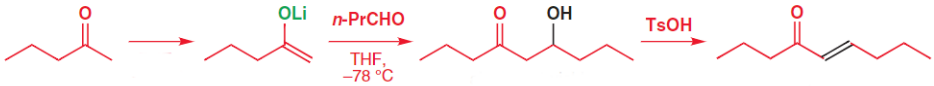
5) Chemistry – *Short Answer* Identify all of the following 3 moieties that would experience chirality without an sp3 hybridized carbon: 1) Allenes; 2) Binap; 3) Aziridines.

ANSWER: 1 AND 2 [DJ]

Commented [1]: this is shitty worded, apc help

VISHWAL BONUS

5) Chemistry – *Short Answer* Shown in the image is the reaction of pentan-2-one with butanal in an attempt to generate oct-4-en-3-one. Answer the following 2 questions about this reaction: 1) What is the name of this type of reaction; 2) Identify all of the following 3 bases that would form the enolate depicted: 1) Lithium Methoxide; 2) LDA; 3) KHMDS.



Source: Jonathan Clayden Organic Chemistry ch26
ANSWER: 1) ALDOL REACTION (ACCEPT: ALDOL CONDENSATION AND CROSSED ALDOL); 2) 2 ONLY [DJ]

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TOSS-UP

6) Energy – *Short Answer* Researchers at Argonne National Lab are working to develop catalysts for the production of liquid fuels from methane. Methanation reactions with metal catalysts have been greatly studied for the production of methane to create synthetic natural gas. What process reacts carbon dioxide and hydrogen gas with a nickel catalyst to yield methane and water?

ANSWER: SABATIER PROCESS [ACCEPT: SABATIER REACTION] [TZ]

BONUS

6) Energy – *Short Answer* Scientists at Lawrence Berkeley National Lab have been studying two-dimensional materials. When these one-atom thick layers are stacked on top of each other at an angle, what characteristic pattern is formed?

ANSWER: MOIRÉ PATTERN [CK]
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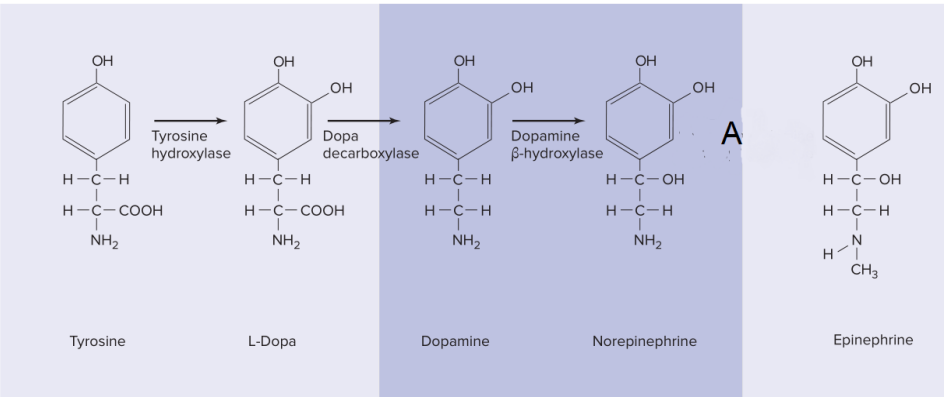
TOSS-UP

7) Biology – *Short Answer* [6] During the formation of a platelet plug, which factor present on the cell membranes of platelets is responsible for helping them adhere to each other and to factor VII?

ANSWER: VON WILLEBRAND FACTOR [Animal Physiology - Circulatory Systems, SF]

VISUAL BONUS

7) Biology – *Short Answer* [8] Shown in the image is a pathway regarding the synthesis of neurotransmitters within the brain. Answer the following 3 questions concerning the image: 1) What is the enzyme labeled A that converts norepinephrine to epinephrine? 2) What is the general name for these compounds derived from tyrosine, containing a benzene ring and 2 hydroxyl groups? 3) What enzyme is responsible for breaking down the compounds mentioned in the previous question in the synaptic cleft?



Source: Vander's Human Physiology [Chapter 6]

ANSWER: 1) PMNT (ACCEPT: PHENYLETHANOLAMINE N-METHYLTRANSFERASE); 2) CATECHOLAMINES; 3) MONOAMINE OXIDASE (ACCEPT: MAO). [ANIMAL PHYSIOLOGY - NERVOUS SYSTEMS, SF]

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TOSS-UP

8) Earth and Space – *Short Answer* [7] What is the name for the specific solution to the Einstein vacuum field equations that describes a charged, nonrotating black hole?

ANSWER: REISSNER-NORDSTROM [Astronomy - Cosmology, SF]
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BONUS

8) Earth and Space – *Short Answer* [7] The Cartwheel galaxy is an example of what general type of galaxy, formed when one smaller companion plunges through a larger one perpendicular to its disk and is characterized by the abundance of black holes and neutron stars?

ANSWER: RING GALAXY [Astronomy - Other, SF]

TOSS-UP

9) Chemistry – *Short Answer* What equation in chemistry calculates the lattice energy of a crystalline ionic solid that includes a repulsion term which includes the compressibility constant of the crystal?

ANSWER: BORN-MAYER EQUATION [DJ]

BONUS

9) Chemistry - Short Answer Identify all of the following three electrocyclic reactions that are correctly paired to their rotary mechanism: 1) 4 pi system photochemical reaction, conrotary; 2) 6 pi system photochemical reaction, conrotary; 3) 8 pi system thermal reaction, disrotatory.

ANSWER: 2 ONLY [YL]

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TOSS-UP

10) Math – *Short Answer* [9] Alice rolls a die repeatedly until she rolls a 1. What is the expected value of the sum of her rolls?

ANSWER: 21 [Com - Dice, CT]

BONUS

10) Math – *Short Answer* [8] What is the largest positive integer x such that $x^2 + 7x + 41$ is a perfect square?

ANSWER: 25 [NT - idk, CT]
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TOSS-UP

11) Energy – *Multiple Choice* Researchers at NIH are studying sleeping habits amongst teenagers using electroencephalograms, or EEGs. As a teenager progresses through the phases of sleep, how do EEG readings change?

W) Higher amplitude and higher frequency
X) Higher amplitude and lower frequency
Y) Shorter amplitude and higher frequency
Z) Shorter amplitude and lower frequency

ANSWER: X) HIGHER AMPLITUDE AND LOWER FREQUENCY [AS]

BONUS

11) Energy – *Short Answer* Scientists at Lawrence Livermore National Lab in collaboration with MIT are using affinity selection followed by tandem mass spectrometry sequencing to identify peptides with high specificities for cardiac tissues. Identify all of the following three amino acids that they excluded from the original synthetic library: 1) Isoleucine; 2) Cysteine; 3) Methionine.

ANSWER: 1 AND 2

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TOSS-UP

12) Physics – *Multiple Choice* [8] Which of the following materials has a resistivity that must be expressed with a tensor?
W) Graphite
X) Copper
Y) Water
Z) Silicon

ANSWER: W) GRAPHITE [E&M, DK]

BONUS

12) Physics – *Short Answer* [9] Identify all of the following quasiparticles that are bosonic: 1) hole, 2) phonon, 3) plasmon.

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

13) Chemistry – *Multiple Choice* Which of the following is the reason that many nucleophilic additions to ketones are acid catalyzed?

W) To make the carbonyl group less sterically hindered
X) To make the carbonyl group more sterically hindered
Y) To make the carbonyl group less electrophilic
Z) To make the carbonyl group more electrophilic

ANSWER: Z) TO MAKE THE CARBONYL GROUP MORE ELECTROPHILIC [DJ]

BONUS

13) Chemistry – *Multiple Choice* Which of the following functional groups are the products of the 1,2 and the 1,4 reduction of 2-cyclohexen-1-one respectively:

W) Alcohol and alcohol
X) Unsaturated ketone and alcohol
Y) Unsaturated alcohol and ketone
Z) Ketone and unsaturated ketone

ANSWER: Y) UNSATURATED ALCOHOL AND KETONE [DJ]

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TOSS-UP

14) Biology – *Multiple Choice* [6] In most plant cell walls, cellulose microfibrils are generally oriented parallel to each other and cross linked by polysaccharides. Relative to these microfibrils, in which direction does the cell wall expand during growth?

W) Parallel to the cellulose microfibrils
X) Parallel to the expansion enzymes
Y) Perpendicular to the cellulose microfibrils
Z) Perpendicular to expansion enzymes

ANSWER: Y) PERPENDICULAR TO THE CELLULOSE MICROFIBRILS [Plants - Physiology, SF]

BONUS

14) Biology – *Short Answer* [8] Identify all of the following three plants that if examined in their roots, would contain scattered vascular bundles: 1) Garden bean; 2) Orchid; 3) Rose.

ANSWER: NONE [Plants - Anatomy Diseases, SF]
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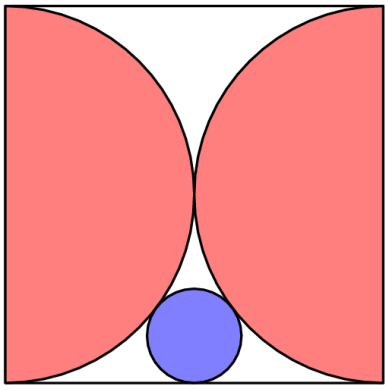
TOSS-UP

15) Math – *Short Answer* [8] If a positive integer has 1000 digits in base 2, how many digits does it have in base 8?

ANSWER: 334 [NT - Base, CT]

VISUAL BONUS

15) Math – *Short Answer* [7] Shown in the image is a unit square with red semicircles of radius 0.5 centered on opposite midpoints. A blue circle is tangent to both semicircles and the square. What is the radius of the blue circle?



ANSWER: 1/8 [Geo - Circ, CT]

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TOSS-UP

16) Earth and Space – *Multiple Choice* [7] Which of the following statements best explains the presence of more than three convection circulation cells in Jupiter's atmosphere?

W) Jupiter's magnetic field causes strong distortions within meridional heat transport
X) Jupiter's rapid rotation causes strong Coriolis deflection
Y) Jupiter's large size limits the size of atmospheric convection cells due to very strong gravity
Z) Helium rain within Jupiter's atmosphere causes significant vertical wind shear

ANSWER: X) JUPITER'S RAPID ROTATION CAUSES STRONG CORIOLIS DEFLECTION [Astronomy - Solar System, YL]

BONUS
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16) Earth and Space – *Short Answer* [8] Identify all of the following 3 climate feedbacks that are positive feedback loops: 1) Carbonate-silicate-weathering feedback; 2) Snow-ice-albedo feedback; 3) Water-vapor-temperature feedback.

ANSWER: 2 AND 3 [Meteorology, YL]

TOSS-UP

17) Energy – *Short Answer* Researchers at Los Alamos National lab have been studying the effects of cholesterol based endocytosis. What is the rate limiting enzyme in the synthesis of cholesterol?

ANSWER: HMG-COA REDUCTASE [SF]

BONUS

17) Energy – *Multiple Choice* Scientists at Brookhaven national labs are studying the activity of fatty acid desaturase enzymes in plant tissues in order to gain insight into how biological systems achieve metabolic channeling. The activity of which of the following enzymes provides a typical example of metabolic channeling?

W) Phosphofructokinase
X) Pyruvate Dehydrogenase
Y) ATP Synthase
Z) Phosphoprotein phosphatase 1

ANSWER: X) PYRUVATE DEHYDROGENASE [DJ]

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TOSS-UP

18) Physics – *Multiple Choice* [6] Which of the following can be placed in parallel with a motor in an AC circuit to increase the real power delivered to it?

W) Capacitor
X) Inductor
Y) Resistor
Z) Rectifier

ANSWER: W) CAPACITOR [Circuits, DK]

BONUS

18) Physics – *Short Answer* [6] A block of mass 30 grams slides down a frictionless ramp from a height of 5 meters. It then moves over a tile floor with a coefficient of friction of 0.4. How many meters will it travel on the floor before coming to rest?

ANSWER: 12.5 [Mech, DK]
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TOSS-UP

19) Math – *Short Answer* [9] Identify all of the following 3 functions that are real analytic over the open set from $x = -1$ to $x = 1$: 1) 1 over x, 2) tangent of x, 3) e to the x.

ANSWER: 2 AND 3 [Calc - Der, CT]

BONUS

19) Math – *Short Answer* [8] If $x + y = 4$ and $x^3 + y^3 = 46$, what is $x^2 + y^2$?

ANSWER: 13 [Alg - LinSys, CT]

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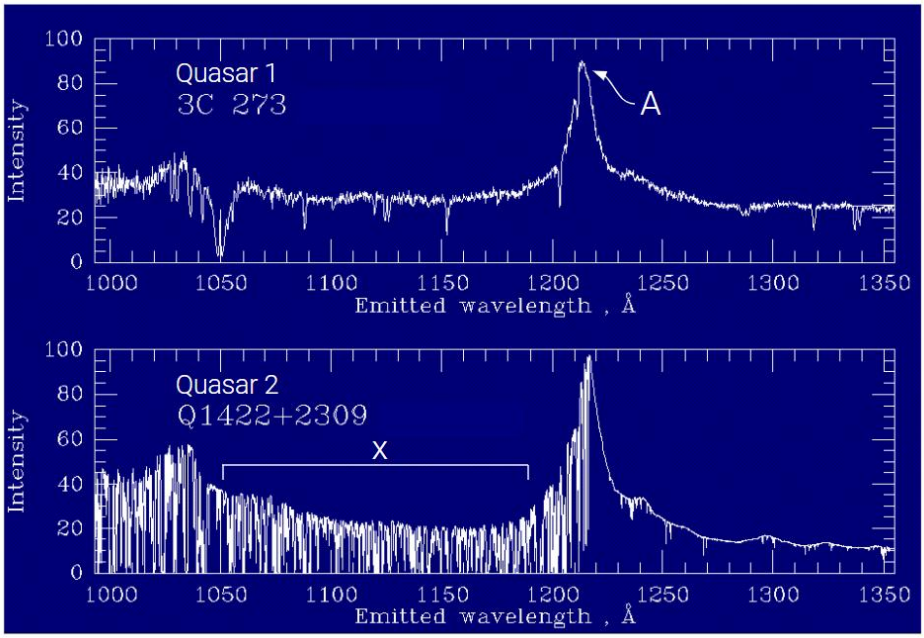
TOSS-UP

20) Earth and Space – *Short Answer* [8] Identify all of the following changes that would lead to a broadening of a sodium spectral line from a stellar atmosphere: 1) Increasing the concentration of sodium; 2) Increasing the temperature of the atmosphere; 3) Decreasing the degree of atmospheric circulation.

ANSWER: 1 AND 2 [Astronomy - Stellar, YL]

VISHWAL BONUS

20) Earth and Space – *Short Answer* [9+] Shown in the image are redshift-adjusted spectra diagrams of two quasars, labelled Quasar 1 and Quasar 2. Answer the following three questions regarding the image: 1) In which region of the electromagnetic spectrum is the emission peak labelled A? 2) What is the region labelled X known as? 3) Which quasar is further away from Earth?
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ANSWER: 1) ULTRAVIOLET; 2) LYMAN-ALPHA FOREST; 3) QUASAR 2 [Astronomy - Cosmology, YL]

TOSS-UP

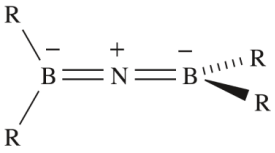
21) Chemistry – *Multiple Choice* In transition state theory, the Eyring equation can be used to model reaction rates. When compared to the Arrhenius equation, which of the following quantities is most analogous to the activation energy?

W) Enthalpy of activation
X) Gibbs free energy of activation
Y) Entropy of activation
Z) Transmission coefficient

ANSWER: W) ENTHALPY OF ACTIVATION

VISHWAL BONUS

21) Chemistry – *Short Answer* Answer the following two questions regarding the figure shown: 1) Rank the following three boron nitrides in terms of increasing average B-N bond length; 2) The compound denoted 1 is analogous to what class of organic compounds?



1

$B_3N_3H_6$

2

H_3CBNCH_3

3

ANSWER: 1) 3, 1, 2; 2) ALLENES [YL]

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TOSS-UP

22) Biology – *Short Answer* [7] What is the analogous set of genes in plants to the HOX genes in animals that are responsible for flower development?

ANSWER: MADS-BOX [Plants - Physiology, SF]

BONUS
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22) Biology – *Short Answer* [8] Identify all of the following three statements that are true of an ELISA: 1) Unlike an western blot, it may not be used to detect native proteins; 2) Horseradish peroxidase is commonly used to detect antibody binding; 3) It may be used to detect the presence or absence of specific proteins.

ANSWER: 2 AND 3 [Cell Biology - Biotech, SF]

TOSS-UP

23) Physics – *Multiple Choice* [5] In celestial mechanics, the effective potential is used to convert a two-body problem to a one-body one. It is defined as the sum of the potential energy and what other quantity?

W) Moment of inertia
X) Reduced mass
Y) Radial kinetic energy
Z) Angular kinetic energy

ANSWER: Z) ANGULAR KINETIC ENERGY [Mech, DK]

BONUS

23) Physics – *Short Answer* Identify all of the following three constituent quarks that may be found in a delta baryon: 1) Up quark; 2) Strange quark; 3) Top quark.

ANSWER: 1 ONLY