MHS Round 17

Buzzer test + Ice breaker question: What did you think of our set?

TOSS-UP

1) Physics – *Short Answer* A monatomic gas expands adiabatically from a volume of 27 liters to 64 liters. If the initial pressure of the gas is 1024 mmHg, what is the final pressure of the gas in mmHg?

ANSWER: 243

BONUS

1) Physics – *Short Answer* Identify all of the following three statements that are true of conductors. 1) There is no net electric field inside a conductor. 2) Conductors have equal potential across their surface only if they are gaussian. 3) The pressure on a conductor is equivalent to the energy density of the electric field outside the conductor.

ANSWER: 1, 3, 2

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TOSS-UP

2) Earth and Space – *Multiple Choice* Which of the following minerals experiences the greatest rate of weathering?

W) Muscovite
X) Anorthite
Y) Enstatite
Z) Orthoclase

ANSWER: X) ANORTHITE

BONUS

2) Earth and Space – *Multiple Choice* Which of the following types of volcanic eruptions would be most likely to produce a caldera?

W) Plinian
X) Hawaiian
Y) Vulcanian
Z) Surtseyan

ANSWER: W) PLINIAN
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TOSS-UP

3) Chemistry – *Short Answer* Order the following 3 steps of the Suzuki coupling reaction from first to last to occur starting from Palladium 0: 1) Transmetalation; 2) Oxidative addition; 3) Reductive elimination.

ANSWER: 2, 3, 1

BONUS

3) Chemistry – *Multiple Choice* In the nitration of aniline, it is observed that the product adds the NO_2 group to the meta position more than it would be expected based on the activation of the ring. Which of the following must be true regarding this reaction?

W) Aniline is meta directing.
X) The sigma complex is stabilized by an unusually high number of resonance structures.
Y) There is excess Bronsted Lowry acid in solution.
Z) A benzyne intermediate must be formed.

ANSWER: Y) THERE IS EXCESS BRONSTED LOWRY ACID IN SOLUTION

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TOSS-UP

4) Biology – *Short Answer* The SDR or Shortchain Dehydrogenase Reductase family of enzymes binds to what two other biological molecules?

ANSWER: NAD+ AND NADP+

BONUS

4) Biology – *Short Answer* Freedivers often voluntarily hyperventilate before a deep dive to increase the length of time they can hold their breath. If a sample were taken from the blood of a freediver immediately after hyperventilation, identify all of the following 3 choices that would increase: 1) Hematocrit; 2) Hemoglobin affinity for oxygen; 3) pH.

ANSWER: 3 ONLY
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TOSS-UP

5) Math – *Short Answer* Consider the signal f(t) = $cos(10\pi t) * cos(14\pi t)$. Using the standard unitary Fourier transform that returns ordinary, not angular, frequencies, at which of the following frequencies would the Fourier transform of f be divergent to infinity?
W) 1
X) 2
Y) 6
Z) 24
ANSWER: X) 2

BONUS

5) Math – *Short Answer* An ant starts at the corner of a cube. At time *t* = 1, 2, 3, and 4, he randomly chooses one of the three adjacent vertices to go to, each with probability ⅓, and zooms there instantaneously. After his four moves, what is the chance he has returned to his starting spot?

ANSWER: 7/27

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TOSS-UP

6) Physics – *Short Answer* Hamilton's principle states that what quantity, which is the time integral of the Lagrangian, must be stationary for a physical process?

ANSWER: ACTION

BONUS

6) Physics – *Multiple Choice* A certain vehicle is capable of accelerating in any direction chosen by its driver, with a maximum possible magnitude of acceleration 1m/s^2. Suppose this car is initially travelling 10m/s northward and wants to turn to be going 10m/s eastward, and the driver wants to complete this turn in as short a time as possible. Which of the following shapes will the car trace from the moment it begins turning to the moment it finishes turning?

W) Part of a cycloid
X) Part of a circle
Y) Part of a parabola
Z) Part of a hyperbola

ANSWER: Y) PART OF A PARABOLA
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TOSS-UP

7) Earth and Space – *Short Answer* What period of Mars's history was marked by a decrease in bombardment and massive lava flows throughout the planet?

ANSWER: HESPERIAN PERIOD

BONUS

7) Earth and Space – *Short Answer* Identify all of the following three statements that are true of subduction: 1) Blueschist is commonly formed at subduction zones; 2) The Wadati-Benioff zone is a zone of seismicity found at subduction zones; 3) Slab pull is the primary force behind subduction.

ANSWER: ALL

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TOSS-UP

8) Energy – *Short Answer* Researchers at Pacific Northwest national laboratory are studying the adsorption of water onto alumina as an approximate form of gibbsite. Identify all of the following 3 solutions that can dissolve alumina: 1) Pure water; 2) Concentrated hydrofluoric acid; 3) Concentrated sodium hydroxide

ANSWER: 2 AND 3

BONUS

8) Energy – *Short Answer* Scientists at Princeton Plasma Physics Lab must confine hot plasmas in fusion research. What device that can temporarily confine charged particles consists of two coaxial magnetic mirrors or solenoids separated longitudinally?

ANSWER: MAGNETIC BOTTLE
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TOSS-UP

9) Biology – *Short Answer* The thin filament of muscle contains actin, tropomyosin, and troponin C, among other proteins. Troponin C is the calcium-sensing component of the complex. Which of the following motifs would you expect to find in troponin C?

W) Greek key
X) Rossman Fold
Y) Tim Barrel
Z) EF Hand

ANSWER: Z) EF HAND

BONUS

9) Biology – *Multiple Choice* Chemical cross-linking of proteins is an established method for obtaining rough structural information about protein complexes. By identifying the cross-linked residues of neighboring proteins, spatial alignments can be deduced and a rough three-dimensional model can be built. You have a suspicion that aspartates may be at the interface of a protein complex you are studying. Which of the following compounds would you use in an experiment designed to test your hypothesis?

W) N-hydroxysuccinimide

X) 2-phenylglyoxal

Y) 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide

Z) 2,4,6-trinitrobenzene sulfonic acid

ANSWER: Y) 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide

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TOSS-UP

10) Math – *Short Answer* How many edges are in a complete graph with 24 vertices?

ANSWER: 276

BONUS

10) Math – *Short Answer* Consider a continuous function *f* from [0, 1] to [0, 1] * [0, 1] (READ AS: ***"f from the closed interval from 0 to 1 to the two-dimensional real unit square"***), with R being the set of real numbers. Which of the following could this function *f* be? 1) injective, 2) surjective, 3) bijective

ANSWER: 1 and 2
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TOSS-UP

11) Physics – *Short Answer* What type of precession occurs due to the curvature of spacetime?

ANSWER: DE SITTER (ACCEPT: GEODETIC EFFECT)

BONUS

11) Physics – *Short Answer* A soap bubble with a total charge Q uniformly distributed over its spherical surface is currently at equilibrium. If the pressure inside the soap bubble is identical to that outside, by what factor is the equilibrium radius multiplied by if the surface tension of the bubble is halved?

ANSWER: CUBE ROOT OF 2

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TOSS-UP

12) Earth and Space – *Short Answer* Identify all of the following three types of tornadoes that are non supercell tornadoes: 1) Gustnado; 2) Landspouts; 3) Waterspouts.

ANSWER: ALL

BONUS

12) Earth and Space – *Short Answer* The bora in the Adriatic coast is an example of what type of wind, occurring when cool, dense air rushes down elevated slopes at high speeds?

ANSWER: KATABATIC WINDS
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TOSS-UP

13) Energy – *Multiple Choice* Scientists at Lawrence Livermore national lab are studying closo-borate molecules to act as electrolytes in lithium-ion batteries. One specific closo-borate derivative has a total of 12 boron atoms, taking the shape of what platonic solid?

W) Cube
X) Octahedron
Y) Dodecahedron
Z) Icosahedron

ANSWER: Z) ICOSAHEDRON

BONUS

13) Energy – *Short Answer* Scientists at Sandia national lab are studying ways to clean concrete contaminated with sarin, a nerve agent. Sarin is potent because it inhibits the activity of what enzyme in nerve cells?

ANSWER: ACETYLCHOLINESTERASE

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TOSS-UP

14) Chemistry – *Short Answer* In the epoxidation of a 2-cyclohexen-1-ol you noticed that the epoxidation occurs in a cis manner with a 10: 1 diaestomeric ratio, but if instead of the hydroxyl group you have TBS you observe a 71:10 trans to syn ratio. What interaction in the intermediate most likely causes this observation?

ANSWER: HYDROGEN BONDS

BONUS

14) Chemistry – *Multiple Choice* Which of the following best explains why in the addition of an electrophile on an endo lithium enolate with 1,5 phenyl stereocontrol, attack on the bottom face is favored, generating a syn relationship.

W) Attack of the bottom face avoids interactions with the phenyl group.
X) Attack on the bottom face goes through a chair like transition state.
Y) Attack on the top face has negative flag pole interactions.
Z) Attack on the top face has negative A1,3 strain.

ANSWER: X) ATTACK ON THE BOTTOM FACE GOES THROUGH A CHAIR LIKE TRANSITION STATE.
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TOSS-UP

15) Math – *Short Answer* What is the least positive integer *n* for which the sum of the proper divisors of *n* exceeds *n*?

ANSWER: 12

BONUS

15) Math – *Short Answer* The cross product **a** × **v** can be thought of as a linear transformation acting on **v**. When representing this linear transformation as a matrix-vector product, what is the trace of this matrix in terms of the components a_1, a_2, and a_3?

ANSWER: 0

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TOSS-UP

16) Physics – *Multiple Choice* A massless rope is wrapped around a horizontal pole, subtending an angle of theta, and the coefficient of friction between the rope and the pole is mu. If one end of the rope is attached to a block of mass m, which of the following best describes how much force must be applied at the other end to keep the rope in static equilibrium?

W) Decreases exponentially with theta
X) Increases exponentially with theta
Y) Decreases logarithmically with theta
Z) Increases logarithmically with theta

ANSWER: W) DECREASES EXPONENTIALLY WITH THETA

BONUS

16) Physics – *Short Answer* If the magnetic vector potential is given by (xyz, xyz, xyz), calculate the magnetic field at (1,2,3).

ANSWER: (1, -4, 3)
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TOSS-UP

17) Chemistry – *Multiple Choice* Which of the following is not an example of a Zintl phase?

W) NaSi
X) Cs_2NaAs_7
Y) Mg_3N_2
Z) $K_{12}Si_{17}$

ANSWER: Y) Mg_3N_2

BONUS

17) Chemistry – *Multiple Choice* Which of the following would not be a favored reaction according to Baldwin's rules?

W) 6-Endo-Tet
X) 6-Exo-Tet
Y) 5-Endo-Dig
Z) 3-Exo-tet

ANSWER: W) 6-ENDO-TET

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TOSS-UP

18) Biology – *Multiple Choice* Which of the following does the phosphoryl-transfer reaction not have a role in?

W) Direct repair of alkylated DNA
X) Sanger sequencing of DNA
Y) DNA ligation
Z) Gene transcription

ANSWER: W) DIRECT REPAIR OF ALKYLATED DNA

BONUS

18) Biology – *Short Answer* A particular drug has no effect on the amount of the mature mRNA produced by a gene, but the protein levels are decreased. Which of the following best describes what this drug indicates?

W) Enhances transcription.
X) Inhibits polyA polymerase.
Y) Induces the expression of a miRNA that results in mRNA deadenylation.
Z) Induces the expression of a miRNA that inhibits translation.

ANSWER: Z) INDUCES THE EXPRESSION OF A MIRNA THAT INHIBITS TRANSLATION.
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TOSS-UP

19) Earth and Space – *Short Answer* Identify all of the following three statements that are true of white dwarfs: 1) The Polaris star system contains a white dwarf; 2) DC white dwarfs contain no spectral lines; 3) They can pulsate.

ANSWER: 2 AND 3

BONUS

19) Earth and Space – *Short Answer* What luminosity-temperature relationship that is obeyed by protostars describes a fully convective, opaque star, which shows a nearly vertical curve on the Hertzbrung-Russel diagram?

ANSWER: HAYASHI TRACK

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TOSS-UP

20) Math – *Short Answer* What is the sum of the number of faces and the number of vertices on a regular icosidodecahedron, better known as a standard soccer ball?

ANSWER: 92

BONUS

20) Math – *Short Answer* Identify all of the following that are true given that one and only one choice for the truth values of 1, 2, and 3 is consistent.

1. 2 is false
2. 3 is true
3. both 1 and 2 are false

ANSWER: 1 ONLY
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TOSS-UP

21) Biology – *Short Answer* The hydroxyl group that cleaves DNA from the enzyme topoisomerase comes from which of the following?

W) A serine in topoisomerase.
X) The 5' end of DNA.
Y) A tyrosine in topoisomerase.
Z) The 3' end of DNA

ANSWER: Y) A TYROSINE IN TOPOISOMERASE

BONUS

21) Biology – *Multiple Choice* The binding rates or k_{on} (little k on) for Drugs A and B are the same. However, Drug A has a much higher affinity for its target than does Drug B. Which of the following must be true?

W) The K_d for drug A is greater than the K_d for drug B.
X) The k_{off} (little k off) for Drug B is less than the k_{off} for Drug A.
Y) The k_{off} (little k off) for Drug B is greater than the k_{off} for Drug A.
Z) The K_d for drug A is equal to the K_d for drug B.

ANSWER: Y) THE K_{OFF} (LITTLE K OFF) FOR DRUG B IS GREATER THAN THE K_{OFF} FOR DRUG A.

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TOSS-UP

22) Chemistry – *Short Answer* An Evan's auxiliary is formed from phenylalanine, and attached onto a lithium enolate. After the lithium enolate reacts with an electrophile, what stereochemical relationship between the phenyl group and the electrophile is most commonly observed?

ANSWER: ANTI

BONUS

22) Chemistry – *Multiple Choice* In the reduction of 2-cyclohexen-1-one $NaBH_4$ generates a mixture of both the 1,2 reduction product and the 1,4 reduction product. Which of the following best describes both the 1,2 product and the 1,4 product?

W) Secondary alcohol, and primary alcohol
X) Tertiary alcohol, and alkyne
Y) Primary alcohol, and aldehyde
Z) Secondary alcohol, and ketone

ANSWER: Z) SECONDARY ALCOHOL, AND KETONE
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TOSS-UP

23) Energy – *Multiple Choice* Scientists at Sandia national lab are studying ways to clean concrete contaminated with the nerve agent sarin. Sarin covalently bonds to nerve enzymes' serine amino acid, with what molecule acting as a leaving group, which is generally not a good leaving group for substitution reactions?

W) Fluoride
X) Chloride
Y) Hydroxide
Z) Hydride

ANSWER: W) FLUORIDE

BONUS

23) Energy – *Short Answer* Researchers at Sandia national lab have developed a way to change thermal conductivity in materials by applying an electric field. The applied electric field changes the thermal conductivity of these materials due to the scattering of what quasiparticles?

ANSWER: PHONONS