TOSS-UP

1. Chemistry *Short Answer* Most ligands that bond to metals contain electrons that they donate when participating in bonding. However, certain Lewis acids such as BF_3 instead *accept* electrons from the metal. What is the name of this class of ligands?

ANSWER: Z-TYPE LIGAND (ACCEPT: Z-LIGAND) **[YL]**

BONUS

1. Chemistry *Short Answer* Identify all of the following four carbenes that have unpaired electrons:

1) CCl_2
2) CH_2
3) $C(CH_3)_2$
4) $C(OH)_2$.

ANSWER: 2 AND 3 **[YL]**

TOSS-UP

2. Math *Multiple Choice* When using variation of parameters to solve a linear non-homogeneous differential equation, Cramer's rule can often be used. What is the name of the matrix in the denominator when finding solutions?

W) Jacobian matrix
X) Wronskian matrix
Y) Hessian matrix
Z) Hermitian matrix

ANSWER: X) WRONSKIAN MATRIX **[YL]**

BONUS

2. Math *Short Answer* Yunyi is soaring through the sky in War Thunder. His plane's y-coordinate can be modeled as y=ln(x), and his plane's z-coordinate can be modeled as z=y^3. Given that his plane's x-coordinate is changing at a rate of 5 meters per second, at what rate is his plane's z-coordinate changing in meters per second when his x-coordinate is 1/e?

ANSWER: 15e **[KD]**

TOSS-UP

3. Earth and Space *Short Answer* Identify all of the following four objects that possess a solar wind-induced ion tail?

1) Mercury
2) Venus
3) The Moon
4) Comet Bernadelli-Bernstein

ANSWER: ALL **[SC]**

BONUS

3. Earth and Space *Short Answer* Zoe is examining the light curve of a potential exoplanet candidate. Identify all of the following 3 objects that can be differentiated from exoplanets by examining the slope of the light curve as transit begins and ends:

1) Eclipsing binary
2) Starspot
3) Brown dwarf

ANSWER: 2 ONLY **[SC]**

TOSS-UP

4. Biology *Multiple Choice* A patient's electrocardiogram is observed to have more P waves than QRS complexes, but no relationship between their timing. In addition, the P-P interval has a regular duration. Which of the following heart conditions does the patient most likely have?

W) Supraventricular tachycardia
X) Third Degree AV Block
Y) Atrial Fibrillation
Z) Sinus Arrhythmia

ANSWER: X) THIRD DEGREE AV BLOCK **[KD]**

BONUS

4. Biology *Multiple Choice* An unknown molecule is found in the wild and tested in the lab to find out its identity. The molecule yields a positive test when treated with Benedict's solution, but yields a negative test when treated with Bradford's reagent and Tollen's reagent. Which of the following is MOST likely to be the unknown molecule?

W) Dihydroxyacetone
X) Glucose

Y) Glyceraldehyde
Z) Myosin

ANSWER: W) DIHYDROXYACETONE **[KD]**

TOSS-UP

5. Physics *Short Answer* The supersymmetry model states that every lepton has its accompanying symmetry boson and vice versa. What is the name for the hypothetical supersymmetric partner of the photon?

ANSWER: PHOTINO **[YL]**

LONG BONUS

5. Physics *Short Answer* An irregular asteroid has 3 different principal moments of inertia and is given some angular velocity unaligned with any of them. Answer the following four questions about its rotation.

1) What is the term for the kind of motion the asteroid is experiencing?
2) Can a torque of constant magnitude stop this kind of motion?
3) What equations govern this kind of motion?
4) What is the term for the envelope that bounds the asteroid's angular velocity?

ANSWER: 1: TUMBLING; 2: YES; 3: EULER RIGID BODY EQUATIONS; 4: POINSOT ELLIPSOID **[SC]**

TOSS-UP

6. Chemistry *Multiple Choice* Which of the following coupling reactions does NOT involve transmetallation as a key step?

W) Heck Coupling
X) Kumada Coupling
Y) Stille **[still]** Coupling
Z) Negishi **[ney-GEE-shee]** Coupling

ANSWER: W) HECK COUPLING **[YL]**

BONUS

6. Chemistry *Multiple Choice* Which of the following complexes follows the 18-electron rule?

W) $PtCl_2(NH_3)_2$
X) $Pd(PPh_3)_4$
Y) $NiCl_4^{2-}$
Z) $PdCl_4^{2-}$

ANSWER: X) $Pd(PPh_3)_4$ **[YL]**

TOSS-UP

7. Math *Multiple Choice* Which of the following differential equations is separable?

W) $y'=(y+x)/y$
X) $y' + y = x$
Y) $y^2y' = x+y$
Z) $y' = 6x^2y$

ANSWER: Z) $y'=6x^2y$ **[KD]**

BONUS

7. Math *Short Answer* Find all eigenvalues for the matrix with first row 1, 9 and second row 4, 1.

ANSWER: 7, -5 (ACCEPT: -5, 7) **[YL]**

TOSS-UP

8. Earth and Space *Short Answer* Because he missed the eclipse, Stephen is slowly moving a very lumpy, but roughly spherical fruit in front of the Sun. Identify all of the following three eclipse effects that he would still observe?

1) Shadow bands
2) Bailey beads
3) Diamond ring effect

ANSWER: 2 AND 3 **[SC]**

BONUS

8. Earth and Space *Multiple Choice* Which of the following objects likely did not contribute substantially to cosmological reionization?

W) Quasars
X) Stellar winds

Y) Supernovae
Z) Dwarf galaxies

ANSWER: X) STELLAR WINDS **[SC]**

TOSS-UP

9. Biology *Short Answer* A restriction enzyme cuts a long strand of DNA at the sequence AAA and makes 5 fragments. Assuming each base is equally likely to occur, how many fragments would be expected to result from a restriction enzyme cutting at the sequence GG in the same DNA strand?

ANSWER: 17 (DO NOT ACCEPT: 20) **[KD]**

BONUS

9. Biology *Short Answer* Identify all of the following 3 types of drugs that would cause an increase in blood pressure:

1) Calcium channel blocker in arteries
2) ANP receptor antagonist
3) ADH receptor agonist

ANSWER: 2 AND 3 **[KD]**

TOSS-UP

10. Physics *Short Answer* Identify all of the following 3 statements that are true about magneto-optical traps?

1) They use lasers bluer than the resonant frequency of the atoms
2) They incorporate circularly polarized lasers
3) They cannot cool samples below the Doppler limit

ANSWER: 2 AND 3 **[SC]**

LONG BONUS

10. Physics *Short Answer* Zoe has constructed a parabolic rotating liquid mirror. Find the power of angular velocity that the following two quantities are proportional to:

1) Power of the mirror
2) Vertical height of the mirror

ANSWER: 1: -2; 2: 2 **[SC]**

TOSS-UP

11. Chemistry *Multiple Choice* Kwanga has a container separated into two compartments by an impermeable wall. The left compartment is full of a gas A and the right compartment is full of a gas B, both at equal pressures and temperatures. The wall is then removed and the entropy change S_1 is measured. If instead the left and the right compartments were both filled with gas A, how would the new entropy change S_2 compare to S_1?

W) S_2 is equal to 0
X) S_2 is between 0 and S_1
Y) S_2 is equal to S_1
Z) S_2 is greater than S_1

ANSWER: W) S_2 IS EQUAL TO 0 **[YL]**

LONG BONUS

11. Chemistry *Short Answer* Anurag is attempting to determine the identity of a mystery organic compound **A**. IR spectroscopy of compound **A** shows a single sharp peak at 1715 cm^{-1}. Proton NMR with peak integration shows 10 hydrogen atoms; a 5-hydrogen multiplet at 7.5 Hz, a 2-hydrogen singlet at 3.8 Hz, and a 3-hydrogen singlet at 2.2 Hz. Given that this mystery compound has chemical formula $C_9H_{10}O$, answer the following two questions about compound **A**:

1) What is the name for compound **A**?
2) In the reductive amination of compound **A**, what cyanide-containing reagent should he use that can react with the iminium intermediate but not with the original carbonyl?

ANSWER: 1) PHENYLACETONE (ACCEPT: PHENYLPROPANONE); 2) $NaBH_3CN$ (ACCEPT: SODIUM CYANOBOROHYDRIDE) **[YL]**

TOSS-UP

12. Math *Short Answer* What is the maximum number of intersections between two non-congruent elliptic curves?

ANSWER: 6 **[SC]**

LONG BONUS

12. Math *Short Answer* The numbers 1 through 64 are written in a circle. Jason crosses out every other number starting with 2. When he goes through the circle once, he reverses, crossing out every other number starting with 64. If he repeats this process, what is the last number that will remain?

ANSWER: 43 **[EZ]**

TOSS-UP

13. Earth and Space *Multiple Choice* Which of the following accurately describes downbursts?

W) They form beneath vertically developed clouds
X) They carry considerable moisture content
Y) They have minimal rotational components
Z) They consist of rapidly descending cold air

ANSWER: X) THEY CARRY CONSIDERABLE MOISTURE CONTENT **[SC]**

BONUS

13. Earth and Space *Multiple Choice* Mylonite is a very fine-grained rock resulting from dynamic metamorphism. Which of the following features is most likely to contain mylonite at depth?

W) Mid-ocean ridge
X) Contact aureole
Y) Detachment fault
Z) Impact crater

ANSWER: Y) DETACHMENT FAULT **[KW]**

TOSS-UP

14. Biology *Multiple Choice* Which of the following cellular situations would be the most likely to be analyzed by Fluorescence Resonance Energy Transfer, or FRET?

W) Diffusion of phospholipids in the plasma membrane
X) Dimerization of Receptor Tyrosine Kinases
Y) Point Mutations in DNA
Z) Synthesis of carbohydrates in the Golgi Apparatus

ANSWER: X) DIMERIZATION OF RECEPTOR TYROSINE KINASES **[KD]**

BONUS

14. Biology *Multiple Choice* Steph is playing with his two pet bananas when he notices that they both have the same mutant phenotype. He wants to find out more about the genetic basis of this mutation so he crosses the bananas. Which of the following findings would most likely suggest that the two bananas have mutations in DIFFERENT genes, given that the mutations are recessive?

W) The F1 generation dies immediately following birth
X) The F1 generation is composed of only mutant bananas
Y) The F1 generation is composed of half mutant bananas and half wild type bananas
Z) The F1 generation is composed of only wild type bananas

ANSWER: Z) THE F1 GENERATION IS COMPOSED OF ONLY WILD TYPE BANANAS **[KD]**

TOSS-UP

15. Physics *Multiple Choice* Eric is examining data from Blair Science Bowl C Team's low-energy particle accelerator. He notices a baryonic particle with a charge of exactly twice the elementary charge and a mass similar to that of a proton. What has he found?

W) Xi baryon
X) Lambda baryon
Y) Delta baryon
Z) Pentaquark

ANSWER: Y) DELTA BARYON **[SC]**

BONUS

15. Physics *Short Answer* For the second time in his life, Yunyi has found a negative magnetic monopole floating in space. Again horrified, he throws a conducting spherical shell in a straight line at it from a long distance without any spin. What happens?

W) The shell is deflected to Yunyi's left
X) The shell is deflected to Yunyi's right
Y) The shell hits the monopole straight on faster than it was thrown
Z) The shell hits the monopole straight on slower than it was thrown

ANSWER: Z) THE SHELL HITS THE MONOPOLE STRAIGHT ON SLOWER THAN IT WAS THROWN **[SC]**
(Solution: By symmetry, the shell cannot be deflected. However, approaching the monopole induces a solenoidal current in the shell, which produces a magnetic field inside it. This "steals" its stored energy from the kinetic energy of the shell, slowing it down.)

TOSS-UP

16. Chemistry *Short Answer* In six-membered rings in the chair conformation, bulkier groups typically prefer equatorial positions due to steric reasons. However, in some sugars, substituents alpha to the ring oxygen may actually prefer the axial position due to stronger orbital interactions. What is the name of this effect?

ANSWER: ANOMERIC EFFECT [**YL]**

BONUS

16. Chemistry *Short Answer* The ground state energy of a 1D particle in a box with length 1 Angstrom is 38 electron volts. In electron volts, what is the energy of the first excited state of a 3D particle in a box with lengths of 1 Angstrom, 2 Angstroms, and 4 Angstroms?

ANSWER: 57 eV **[YL]**

TOSS-UP

17. Math *Short Answer* Farmer Yunyi has 200 heads on his farm not including himself. He has some chickens with 1 head and 2 legs each and some chimeras with 3 heads and 4 legs. If the farm has a total of 350 legs not counting his own, how many animals are on the farm?

ANSWER: 150 **[EZ]**

LONG BONUS

17. Math *Short Answer* Farmer Yunyi's chimeras are jumping around in 3 dimensional space. Each jump, they go +1 units in one direction, +2 units in another, and +3 units in the third. If they start at the origin, how many ways are there for them to get to the point (12,12,12) in 6 hops?

ANSWER: 1620 **[EZ]**

TOSS-UP

18. Earth and Space *Short Answer* Identify all of the following 4 features that are characteristic of severe developing thunderstorms:

1) mammatus clouds
2) strong downdrafts
3) back-sheared anvil clouds
4) mesocyclones.

ANSWER: 1, 3, AND 4 **[KW]**

LONG BONUS

18. Earth and Space *Short Answer* Answer the following three questions about the interior of Callisto.

1) Is Callisto fully differentiated, partially differentiated, or undifferentiated?
2) What two shapes dominate in ice crystals in Callisto's mantle?
3) Does Callisto likely possess a dense metal core?

ANSWER: PARTIALLY DIFFERENTIATED, CUBOIDAL AND TETRAHEDRAL, YES **[SC]**

TOSS-UP

19. Biology *Multiple Choice* A certain patient has been observed to lack S cones in their retina. Which of the following symptoms would you most likely expect to see in this patient?

W) Inability to distinguish between red and green
X) Inability to distinguish between red and black
Y) Inability to distinguish between green and black
Z) Inability to distinguish between blue and black

ANSWER: Z) INABILITY TO DISTINGUISH BETWEEN BLUE AND BLACK **[KD]**

BONUS

19. Biology *Short Answer* A sudden outbreak of anithumoral debogglation has occurred and it has already infected 2% of the population. Luckily, Steph was fast to act and already made a test to detect the disease. The test has been shown to have 94% specificity and 100% sensitivity. Given that Evan recently took the test and it sadly reported positive, what is the percent probability he actually has antihumoral debogglation?

ANSWER: 25% **[KD]**

TOSS-UP

20. Physics *Short Answer* With his mind powers, Yunyi induces a monotonic temperature gradient in a uniform metal rod. He then runs a current through the rod, from the cold end to the hot end. To his surprise, this causes the temperature gradient to become less steep. What effect is Yunyi observing?

ANSWER: THOMPSON EFFECT (ACCEPT: CONTINUOUS PELTIER EFFECT, DO NOT ACCEPT: PELTIER EFFECT OR SEEBECK EFFECT) **[SC]**

BONUS

20. Physics *Short Answer* Two relativistic particles of mass m are traveling in opposite directions at speeds of 0.6 c and 0.8 c relative to the lab frame. Then, they collide head-on and stick together. Brian is moving at a velocity of 0.4 c relative to the lab frame, parallel to the masses. Which of the following four quantities related to this event are the same for both Brian and an observer in the lab frame?

1) Energy of emitted photon
2) Direction of emitted photon
3) Relative velocity of the masses at impact
4) Speed of the final mass relative to the lab frame

ANSWER: 4 ONLY **[SC]**

TOSS-UP

21. Chemistry *Short Answer* Identify all of the following three enol derivatives that can act as a nucleophile in an aldol addition without the presence of any other reagents:

1) Lithium enolate
2) Aza enolate
3) Silyl enol ether

ANSWER: 1 AND 2 **[YL]**

BONUS

21. Chemistry *Short Answer* Gaseous PCl_3 and Cl_2 are placed inside a container capped with a moveable piston so that the pressure within the container always equals atmospheric pressure. Given that the reaction PCl_3 (g) + Cl_2 (g) → PCl_5 (g) **(READ AS: PCl_3 gaseous plus Cl_2 gaseous yields PCl_5 gaseous)** is exothermic, identify all of the following four changes that would increase the number of moles of PCl_3 inside the chamber:

1) Doubling atmospheric pressure
2) Adding gaseous PCl_3
3) Adding inert argon gas
4) Increasing the temperature

ANSWER: 2, 3, AND 4 **[YL]**

TOSS-UP

22. Math *Short Answer* A point X is chosen on the circumcircle of triangle ABC. The feet of the altitudes from X to each side of the triangle are collinear, lying on what line?

ANSWER: SIMPSON'S LINE **[EZ]**

BONUS

22. Math *Short Answer* A polygon has infinite vertices, located at (1/(2^n), 1/(3^n)) for all nonnegative integers n. What is the area of the polygon?

ANSWER: 1/5 **[EZ]**

TOSS-UP

23. Earth and Space *Multiple Choice* The starship BSS *Selfish Machines* is moving away from Earth at a constant velocity of 0.8 c. Compared to an observer on Earth, which of the following parameters of the Cosmic Microwave Background would be different if measured from this ship?

W) Polarization
X) Temperature
Y) Primary anisotropy
Z) Dipole anisotropy

ANSWER: Z) DIPOLE ANISOTROPY **[SC]**

BONUS

23. Earth and Space *Short Answer* Identify all of the following 3 unconformities that could divert a stream downcutting past the level of the unconformity:

1) Disconformity
2) Nonconformity
3) Angular unconformity.

ANSWER: 3 ONLY **[KW]**

TOSS-UP

24. Biology *Short Answer* Yunyi and Stephen each found a lipid and want them to undergo beta-oxidation to obtain more Acetyl-CoA. Given that Yunyi's lipid has 500 fatty acids and Stephen's lipid has 5 fatty acids, in which organelles would Yunyi's and Stephen's lipids, respectively, undergo beta-oxidation?

ANSWER: PEROXISOME AND MITOCHONDRION **[KD]**

BONUS

24. Biology *Short Answer* Order the following 4 molecules in cellular respiration in terms of increasing average oxidation state of Carbon:

1) Oxaloacetate
2) Glucose
3) Citrate
4) Pyruvate

ANSWER: 2, 4, 3, 1 **[KD]**

TOSS-UP

25. Physics *Short Answer* The Lorenz gauge transforms the electric scalar and magnetic vector potentials such that they are both written as the same operator applied to charge and current density, respectively. What is the term for this operator?

ANSWER: THE D'ALEMBERTIAN (ACCEPT: WAVE OPERATOR) [**SC]**

BONUS

25. Physics *Short Answer* Identify all of the following three statements that are true about rapidity in special relativity:

1) It adds linearly under Lorentz transformations
2) It asymptotically approaches 1 as velocity approaches c
3) It can be negative

ANSWER: 1 ONLY **[W: SC, E: ; P LDE]**