# FE!M 2025

## Round 10

### TOSS UP

1) CHEMISTRY *Multiple Choice* Which of the following is the kinetic product in the reaction between cyclopentadiene and maleic anhydride?

W) endo cis-norbornene

X) endo trans-norbornene

Y) exo cis-norbornene

Z) exo trans-norbornene

ANSWER: X) endo cis-norbornene [TS]

### BONUS

1) CHEMISTRY *Short Answer* Scientists at Savannah River National Labs are studying gas-phase reaction kinetics. Although the Arrhenius equation can be used to describe such phenomena empirically, what other equation based on transition-state theory is used to improve precision and reproducibility of kinetic models?

ANSWER: Eyring equation [TS]

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**TOSS UP**

2) PHYSICS *Short Answer* You have an infinite conducting plane with a hemispherical bump in it. A point charge is placed along the axis perpendicular to the plane and passing through the center of the hemisphere. How many image charges are produced in this configuration?

ANSWER: 3 [RuA]

**BONUS**

2) PHYSICS *Short Answer* When gamma rays are absorbed or emitted by nuclei in a crystal, lattice energy can be lost as recoil energy through phonon emission. What effect describes the absorption or emission of gamma rays in nuclei with no phonon emission, often termed recoil-free events?

ANSWER: Mossbauer Effect [RoA]

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**TOSS UP**

3) ESS *Short Answer* Order the following three crystal classes by increasing degree of symmetry:

1) Monoclinic
2) Tetragonal
3) Orthorhombic

ANSWER: 312 [RoA]

**BONUS**

3) ESS *Multiple Choice* According to the mass-luminosity relation, which of the following times in years is closest to the lifetime of a 4 solar mass star?

W) $9 * 10^7$

X) $3 * 10^8$

Y) $9 * 10^8$

Z) $3 * 10^8$

ANSWER: X) $3 * 10^9$ [RoA]

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**TOSS UP**

4) MATH *Multiple Choice* According to Benford's law, which of the following percentages is closest to the proportion of numbers in a numerical set which have a leading digit of 1?

W) 10

X) 30

Y) 50

Z) 70

ANSWER: X) 30

**BONUS**

4) MATH *Short Answer* Find the integral from 1 to 4 of $xe^x$ dx (read: x times e to the power of x dx).

ANSWER: $3e^4$ [TS]

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**TOSS UP**

5) BIOLOGY *Short Answer* Select ALL of the following organisms that likely possess metanephridia:

1) Leech
2) Scorpion
3) Tapeworm

ANSWER: 1 only [TS]

**BONUS**

5) BIOLOGY *Short Answer* In the isolated country of Latveria, 30% of the males in a population satisfying Hardy-Weinberg Equilibrium display the sex-linked dominant trait doomsday. What percentage of females in the population display doomsday?

ANSWER: 51% [TS]

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**TOSS UP**

6) CHEMISTRY *Short Answer* The Reformatsky reaction is an organic chemical reaction that condenses an alpha-halo ester with an aldehyde or a ketone using a zero-valent metal. What specific metal is typically used in the Reformatsky reaction to form a non-enolizable organozinc intermediate?

ANSWER: Zn

**BONUS**

6) CHEMISTRY *Short Answer* An isotope X-137 decays by beta emission with a half-life of 12.0 hours and by alpha decay with a half-life of 18.0 hours. Giving your answer to two significant figures, what is the overall half-life of X-137?

ANSWER: 7.2 h [AA]

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**TOSS UP**

7) PHYSICS *Short Answer* Which of the following about voltmeters is true?

W) A voltmeter consists of a galvanometer in series with a small resistor

X) A voltmeter consists of a galvanometer in series with a large resistor

Y) A voltmeter consists of a galvanometer in parallel with a small resistor

Z) A voltmeter consists of a galvanometer in parallel with a large resistor

ANSWER: X) A voltmeter consists of a galvanometer in series with a large resistor [RoA]

**BONUS**

7) PHYSICS *Short Answer* Theenash, who lives at sea level, holds two rigid hollow hemispheres of radius 1 m. If the two hemispheres are put together and vacuum is created on the inside of the resulting container, then, to one significant figure, how much force does Theenash need to apply to one of the hemispheres to separate it from the other?

ANSWER: $3 * 10^5$ N [RuA]

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**TOSS UP**

8) ESS *Multiple Choice* Which of the following best describes the circulation pattern of ocean water and lagoon water at Laguna Madre, a hypersaline lagoon?

W) Outflow of lagoon water at surface and inflow of ocean water at depth

X) Inflow of lagoon water at surface and outflow of ocean water at depth

Y) Outflow of ocean water at surface and inflow of lagoon water at depth

Z) Inflow of ocean water at surface and outflow of lagoon water at depth

ANSWER: Z) Inflow of ocean water at surface and outflow of lagoon water at depth [RoA]

**BONUS**

8) ESS *Short Answer* Identify all of the following four types of interactions that occur to a significant extent within muscovite:

1) Covalent bonding

2) Ionic bonding

3) Hydrogen bonding

4) Van der waals forces

ANSWER: ALL [RoA]

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**TOSS UP**

9) MATH *Short Answer* What is the unit vector in the direction of steepest descent of the function f(x, y) = $5x^2 + 2xy + y^3$ at the point (1, 1)?

ANSWER: $(-\frac{12}{13}, -\frac{5}{13})$ [AdM]

**BONUS**

9) MATH *Short Answer* Let $z_1$ and $z_2$ be two twelfth roots of unity. What is the minimum possible distance between $z_1$ and $z_2$ in the complex plane?

ANSWER: $\frac{\sqrt{6}-\sqrt{2}}{2}$ [AdM]

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**TOSS UP**

10) BIOLOGY *Short Answer* Researchers at Ames National Labs are investigating nutrition specific to C4 and CAM plants. In PEP regeneration within these plants, pyruvate is symported from bundle sheath cells alongside what distinctive micronutrient?

ANSWER: Sodium

**BONUS**

10) BIOLOGY *Short Answer* Cribrostatin is a quinoquinoline-based anticancer drug whose mechanism of action primarily hinges on the induction of reactive oxygen species in tumor cells. Select ALL of the following statements that are TRUE of cribrostatin:

1) It increases the NADPH/NADP+ ratio in target cells
2) It was discovered in a metazoan
3) Its molecular structure is likely similar to that of vitamin A

ANSWER: 2 only [TS]

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**TOSS UP**

11) CHEMISTRY *Multiple Choice* A dienone containing both an isolated ketone and an enone is subjected to a mild, selective reducing agent. The reaction is carried out using sodium borohydride in the presence of cerium(III) chloride. Which of the following is the major product of this reduction?

W) Only the isolated ketone is reduced to an alcohol

X) Both the isolated ketone and the enone are reduced to alcohols

Y) The enone is selectively reduced to a saturated alcohol

Z) The enone is selectively reduced at the carbonyl at the carbonyl to form an allylic alcohol

ANSWER: Z) The enone is selectively reduced at the carbonyl at the carbonyl to form an allylic alcohol [AA]

**BONUS**

11) CHEMISTRY *Multiple Choice* A mixture of two enantiomers has an enantiomeric excess of 10%. What is the enantiomeric ratio of this mixture?

ANSWER: 9/11 (ACCEPT: 11/9) [TS]

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**TOSS UP**

12) PHYSICS *Short Answer* Ignition is the point at which a nuclear fusion reaction's energy output exceeds its energy input and it becomes self-sustaining. Identify all of the following changes with all else held constant in a nuclear fusion reaction that would assist with ignition:

1) Increased Bremsstrahlung radiation

2) Increased density

3) Increased energy confinement time

ANSWER: 23 [RoA]

**BONUS**

12) PHYSICS *Multiple Choice* Which of the following best describes how dielectric constant varies with increasing temperature for glass and water respectively?

W) Decreases, increases

X) Stays constant, increases

Y) Increases, decreases

Z) Stays constant, decreases

ANSWER: Z) Stays constant, decreases [RoA]

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**TOSS UP**

13) ESS *Multiple Choice* Which of the following best describes how surface temperatures would change if there was a sudden influx of ozone into the troposphere and into the stratosphere, respectively?

W) Increase, increase

X) Increase, decrease

Y) Decrease, increase

Z) Decrease, decrease

ANSWER: Increase, decrease [IK]

**BONUS**

13) ESS *Short Answer* Order the following four minerals by increasing solubility in ocean water:

W) Halite

X) Gypsum

Y) Calcite

Z) Aragonite

ANSWER: 3421 [RoA]

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**TOSS UP**

14) MATH *Short Answer* A "mountain number" is one which has digits that are strictly increasing, then strictly decreasing. For example, 12321 is a mountain number, while 321 is not. How many 9-digit mountain numbers use the digits from 1 to 9 exactly once?

ANSWER: 254 [AdM]

**BONUS**

14) MATH *Short Answer* Toeball is a sport in which teams can score in groups of 3 or 7 points. How many distinct ending scores of toeball exist (including ties) in which either team scores at most 25 points? Assume that a teams are indistinguishable; in other words, a score of 6 to 3 is the same as a score of 3 to 6.

ANSWER: 190 [AdM]

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**TOSS UP**

15) BIOLOGY *Multiple Choice* Scientists at Thermofisher are studying the structure of human chorionic gonadotropin for pregnancy test design. Which of the following proteins is a paralog of hCG?

W) Prolactin

X) Follicle-stimulating hormone

Y) Luteinizing hormone

Z) Oxytocin

ANSWER: Y) Luteinizing hormone [TS]

**BONUS**

15) BIOLOGY *Short Answer* Base excision repair is a process crucial for the avoidance of point mutations in eukaryotic genomes. Arrange the following 3 steps of base excision repair in chronological order:

1) Nicking by DNA glycosylase

2) Base removal by AP endonuclease

3) Flap removal by flap endonuclease

ANSWER: 213 [TS]

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**TOSS UP**

16) CHEMISTRY *Multiple Choice* Order the following three groups by increasing proportion of E-alkene product in a Wittig reaction if coupled to the ylide carbanion:

1) Ester
2) Methyl
3) Phenyl

ANSWER: 231 [TS]

**BONUS**

16) CHEMISTRY *Short Answer* The first half life of a unimolecular second-order reaction is t. In terms of t, and starting with 1 mol of reactant, how much time elapses until 1/16 mol of reactant remains?

ANSWER: 15t [AA]

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**TOSS UP**

17) PHYSICS *Multiple Choice* At low temperatures, the Debye model can be used to estimate the heat capacity of a solid. Which of the following statements best describes how accurately the Debye model predicts the heat capacity in this regime, and how the heat capacity depends on temperature?

W) Accurate, proportional to $T^3$
X) Accurate, proportional to $T^4$
Y) Inaccurate, proportional to $T^3$
Z) Inaccurate, proportional to $T^4$

ANSWER: W) Accuraate, proportional to $T^3$ [RoA]

**BONUS**

17) PHYSICS *Short ANswer* Advaith develops a new model of intermolecular interactions that he dubs the LBJ potential. According to the LBJ potential, there exists a repulsive force between molecules that scales with the interparticle distance raised to the power of -9. If two particles are initially one meter apart, then by what factor does the LBJ potential of the system change when the particles are moved to a distance of 2 meters apart?

ANSWER: $\frac{1}{1024}$ [RoA]

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**TOSS UP**

18) ESS *Multiple Choice* Which of the following best explains why white dwarfs cannot act as pulsars?

W) White dwarfs do not have strong enough magnetic fields

X) Electron degeneracy pressure cannot support the rapid spin of pulsars

Y) White dwarfs are not massive enough to generate significant radiation

Z) White dwarfs lack free electrons required to generate synchrotron jets

ANSWER: X) Pulsars spin too rapidly for electron degeneracy pressure to hold them together [AS]

**BONUS**

18) ESS *Short Answer* Identify all of the following four quantities for an air parcel that increase with increasing temperature, assuming all other variables remain constant:

1) Water vapor pressure
2) Saturation vapor pressure
3) Relative humidity
4) Dew point

ANSWER: 2 only [RoA]

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**TOSS UP**

19) MATH *Short Answer* What is the integral from 0 to pi of $\cos^2(x)$?

ANSWER: $\frac{\pi}{2}$ [AdM]

**BONUS**

19) MATH *Short Answer* Let S be the set consisting of all first roots of unity, second roots of unity, and so on until the tenth roots of unity. What is the cardinality of S?

ANSWER: 32 [AdM]

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**TOSS UP**

20) BIOLOGY *Short Answer* The frequency of the i allele and B allele in an isolated Amish population under Hardy-Weinberg equilibrium are 0.6 and 0.2, respectively. What is the percentage of individuals in this population with blood type A?

ANSWER: 28% [TS]

**BONUS**

20) BIOLOGY *Multiple Choice* Teratomas are shoot-like tumors that may form in plants as a result of exposure to Agrobacterium Tumefaciens. Increasing the copy number of genes for which of the following processes on the Ti plasmid would most likely result in teratoma formation?

W) Auxin synthesis

X) Cytokinin synthesis

Y) Opine catabolism

Z) Kanamycin resistance

ANSWER: X) Cytokinin synthesis [TS]

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**TOSS UP**

21) CHEMISTRY *Short Answer* Order the following three ketone reactions by increasing $K_{eq}$ for the forward reaction:

1) Acetal formation from cyclohexanone

2) Wolff-Kishner reduction of butanone

3) Cyanohydrin formation from acetone

ANSWER: 132 [EdH]

**BONUS**

21) CHEMISTRY *Multiple Choice* Which of the following best explains why a Grignard reagent cannot act as a Michael donor while Gilman reagents can?

W) Grignard reagents are hard bases while Gilman reagents are soft bases

X) Grignard reagents require acidic workups while Gilman reagents do not

Y) Grignard reagents are more sterically hindered than Gilman reagents

Z) Gilman reagents are more nucleophilic than Grignard reagents

ANSWER: W) Grignard reagents are hard bases while Gilman reagents are soft bases [EdH]

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**TOSS UP**

22) PHYSICS *Short Answer* What effect explains why a rocket engine is more effective at increasing a spacecraft's kinetic energy when the spacecraft is moving quickly?

ANSWER: Oberth effect [RuA]

**BONUS**

22) PHYSICS *Multiple Choice* A small ball of mass 1kg is attached to the end of a 1kg rod of length 2 meters. The rod's free end is then fixed and the system is swung around the fixed end like a pendulum. To the nearest second, what is the period of this pendulum?

ANSWER: 3s [AdM]

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**TOSS UP**

23) ESS *Short Answer* Order the following three cloud condensation nuclei by increasing relative humidity required for water to begin condensing on them:

1) Salt particles
2) Dust particles
3) Soot

ANSWER: 213 [AS]

**BONUS**

23) ESS *Multiple Choice* For a given hydraulic gradient, a rectangular stream bed with which of the following dimensions would have the greatest discharge?

W) 4 meters deep and 6 meters wide
X) 6 meters deep and 4 meters wide
Y) 2 meters deep and 12 meters wide
Z) 12 meters deep and 2 meters wide

ANSWER: W) 4 meters deep and 6 meters wide [RoA]

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**TOSS UP**

24) MATH *Short Answer* What is the circumradius of a triangle with sides of length 13, 14, and 15?

ANSWER: $\frac{65}{8}$ [AdM]

**BONUS**

24) MATH *Short Answer* How many connected non-isomorphic trees exist with exactly 5 indistinguishable vertices?

ANSWER: 3 [AdM]

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**TOSS UP**

25) BIOLOGY *Short Answer* Select ALL of the following quantities that would decrease under application of an uncompetitive inhibitor to an enzyme:

1) $V_{max}$
2) $K_m$
3) x-intercept of Lineweaver-Burk plot

ANSWER: ALL [TS]

**BONUS**

25) BIOLOGY *Short Answer* Unlike those of sea urchins, mammalian sperm must burrow through a layer of cells prior to reaching the zona pellucida of the oocyte. What class of follicular cells comprise this layer?

ANSWER: Granulosa cells [TS]

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