

### **TOSS-UP**

1. Chemistry *Short Answer* While Gibbs Free Energy measures the maximum amount of reversible work at constant pressure, what state function measures the useful work at constant volume?

ANSWER: HELMHOLTZ FREE ENERGY [YL]

### **BONUS**

1. Chemistry *Multiple Choice* For which of the following reactions is the Gibbs Free Energy closest to the enthalpy change?

- W)  $2\text{CO(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)}$  [READ AS: 2 CO gas plus O<sub>2</sub> gas yields 2CO<sub>2</sub> gas]  
X)  $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightarrow 2\text{NH}_3\text{(g)}$  [READ AS: N<sub>2</sub> gas plus 3 H<sub>2</sub> gas yields 2 NH<sub>3</sub> gas]  
Y)  $\text{H}_2\text{(g)} + \text{Br}_2\text{(g)} \rightarrow 2\text{HBr(g)}$  [READ AS: H<sub>2</sub> gas plus Br<sub>2</sub> gas yields 2 HBr gas]  
Z)  $\text{CaCO}_3\text{(s)} \rightarrow \text{CaO(s)} + \text{CO}_2\text{(g)}$  [READ AS: CaCO<sub>3</sub> solid yields CaO solid plus CO<sub>2</sub> gas]

ANSWER: Y)  $\text{H}_2\text{(g)} + \text{Br}_2\text{(g)} \rightarrow 2\text{HBr(g)}$  [YL]

### **TOSS-UP**

2. Math *Short Answer* If the average value of a function f(x) between 2 and 8 is 5, what is the definite integral from 2 to 8 of f(x) - 2?

ANSWER: 18 [CW]

### **BONUS**

2. Math *Short Answer* A falling ping pong ball always bounces up to 3/4 of its original height. If Stanley drops a ball from 40 feet above the ground, how much distance in feet will it bounce?

ANSWER: 280 [EZ]

### **TOSS-UP**

3. Earth and Space *Multiple Choice* Stephen is tunneling through the ground beneath his chair. He observes with disappointment that there is no cross bedding. Which of the following geologic features is Stephen most likely exploring?

- W) Riverbed  
X) Esker  
Y) Turbidite  
Z) Dune

ANSWER: Y) TURBIDITE [KW]

### BONUS

3. Earth and Space *Multiple Choice* What mechanism is most directly responsible for the formation of the Local Bubble?

- W) Centrifugal forces on rotating gas
- X) Past supernovae
- Y) Gravity of nearby clusters
- Z) Stellar winds

ANSWER: X) PAST SUPERNOVAE [SC]

### TOSS-UP

4. Biology *Multiple Choice* A certain bacterial cell in the lab is put into a solution containing high concentrations of glucose and lactose. Which of the following best describes the state of the lac operon in this situation?

- W) Repressed and activated
- X) Repressed but not activated
- Y) Activated but not repressed
- Z) Neither repressed nor activated

ANSWER: Z) NEITHER REPRESSED NOR ACTIVATED [KD]

### BONUS

4. Biology *Short Answer* Dr. Chen is studying bacterial conjugation and genetic recombination in his lab. Identify all of the following 3 statements about bacterial conjugation that are true:

- 1) If an F+ cell and F- cell recombine, the recipient cell is converted into an F+ cell
- 2) If an HFR cell and F- cell recombine, the recipient cell is converted into an F+ cell
- 3) If an HFR cell and F+ cell recombine, the recipient cell is converted into an F+ cell

ANSWER: 1 ONLY [KD]

### TOSS-UP

5. Physics *Multiple Choice* A Carnot engine is operating between a cold reservoir with temperature 300 K and a hot reservoir with temperature 900 K. If 600 J of heat are extracted from the hot reservoir, how much work in Joules is done?

- W) 100
- X) 200
- Y) 300
- Z) 400

ANSWER: Z) 400 [YL]

### BONUS

5. Physics *Short Answer* A uniform solid ball with mass 3 kg and radius 1 m rolls without slipping down a ramp angled at 30° to the horizontal. If the final total kinetic energy of the ball is 1000 J, to two significant figures, what is the final rotational kinetic energy of the ball?

ANSWER: 290 J [YL]

### TOSS-UP

6. Chemistry *Short Answer* In the balanced reaction with lowest integer coefficients between  $\text{MnO}_4^-$  and Fe to form  $\text{Mn}^{2+}$  and  $\text{Fe}^{3+}$ , how many moles of electrons are transferred per mole rxn [read out the letters] of the reaction?

ANSWER: 15 [YL]

### BONUS

6. Chemistry *Short Answer* Order the following three conformations of butane from least to most stable:

- 1) Gauche
- 2) Eclipsed
- 3) Anti

ANSWER: 2, 1, 3 [YL]

### TOSS-UP

7. Math *Short Answer* What is the sum of the largest and smallest possible perimeters of a non-degenerate triangle with integer side lengths and two sides of length 5 and 10?

ANSWER: 50 [CW]

## BONUS

7. Math *Short Answer*: What is the derivative of  $x^2 \sin x$  at  $x = \pi$ ?

ANSWER:  $-\pi^2$  [CW]

## TOSS-UP

8. Earth and Space *Short Answer*: Order the following three planetary bodies in order of increasing estimated surface age.

- 1) Io
- 2) Venus
- 3) Europa

ANSWER: 1, 3, 2 [SC]

## BONUS

8. Earth and Space *Multiple Choice*: Kian is determining the distances of various objects to the Sun. For which of the following objects would spectroscopic parallax not be useful for this task?

- W) A globular cluster in the Milky Way
- X) A dwarf galaxy orbiting the Milky Way
- Y) A star 300 LY from the Sun
- Z) A star 20 LY from the Sun

ANSWER: X) A DWARF GALAXY ORBITING THE MILKY WAY [SC]

## TOSS-UP

9. Biology *Multiple Choice*: Yunyi's vision has been acting up recently so he went to see a doctor and was prescribed glasses with concave lenses. Which of the following conditions does he likely have?

- W) Myopia
- X) Hyperopia
- Y) Presbyopia
- Z) Glaucoma

ANSWER: W) MYOPIA [KD]

## BONUS

9. Biology *Short Answer* Identify all of the following 4 statements that are true about microtubules:

- 1) Extension occurs most quickly at the plus end
- 2) Extension occurs most quickly at the minus end
- 3) Shortening occurs most quickly at the plus end
- 4) Shortening occurs most quickly at the minus end

ANSWER: 1 AND 3 [KD]

#### TOSS-UP

10. Physics *Short Answer* Identify all of the following three processes that exhibit hysteresis.

- 1) Dielectric breakdown
- 2) Plastic deformation
- 3) Ferromagnetism

ANSWER: ALL [SC]

#### BONUS

10. Physics *Short Answer* A solid disk rolls without slipping on a rough surface until it collides elastically against a static wall. After a long time, the disk is again rolling without slipping. What is the ratio of this new speed compared to its initial speed?

ANSWER: 1/3 [SC]

#### TOSS-UP

11. Chemistry *Short Answer* Anurag is attempting to determine the molar mass of a mystery metal by electroplating a solution of the metal chloride and calculating the mass of the electroplated metal. Identify all of the following four quantities that Anurag must know precisely to determine the molar mass of the metal:

- 1) Current
- 2) Electroplating time
- 3) Voltage
- 4) Valency of the metal cation

ANSWER: 1, 2, AND 4 [YL]

## BONUS

11. Chemistry *Multiple Choice* Which of the following metals will give a singlet in an EPR spectrum?

- W) Copper
- X) Iron
- Y) Palladium
- Z) Titanium

ANSWER: Y) PALLADIUM [YL]

## TOSS-UP

12. Math *Short Answer* Yunyi has a bag of marbles. If  $\frac{1}{2}$  are red,  $\frac{1}{3}$  are blue,  $\frac{1}{12}$  are green, and the remaining 6 are yellow, how many marbles are in the bag?

ANSWER: 72 [EZ]

## BONUS

12. Math *Multiple choice* What is the sum of the coefficients in the binomial expansion of the derivative of  $(x+2)^4$  with respect to x?

- W) 96
- X) 108
- Y) 120
- Z) 144

ANSWER: X) 108 [EZ]

## TOSS-UP

13. Earth and Space *Short Answer* Identify all of the following three features that would likely be associated with a radial drainage pattern:

- 1) Mountains
- 2) Endorheic lakes
- 3) Structural basins

ANSWER: 1 [SC]

## BONUS

13. Earth and Space *Short Answer* It is March 20th, and Evan has had enough of daylight savings. Thus, he has placed an automatic water cannon on an altitude-azimuth mount that tracks the Sun across the sky. If he lives at a latitude of 30 degrees north, in simplest radical form, how many times faster is the azimuth of the cannon changing at Noon compared to at sunrise?

ANSWER:  $2\sqrt{3}/3$  [SC]

## TOSS-UP

14. Biology *Multiple Choice* A certain plant flowers when exposed to 14 hours of darkness but does not flower when exposed to 16 hours of darkness. Which of the following could be true of this plant?

- W) It is a short-day plant with critical dark period of 15 hours
- X) It is a long-day plant with critical dark period of 15 hours
- Y) It is a short-day plant with critical dark period of 9 hours
- Z) It is a long-day plant with critical dark period of 9 hours

ANSWER: X) IT IS A LONG-DAY PLANT WITH CRITICAL DARK PERIOD OF 15 HOURS [KD]

## BONUS

14. Biology *Multiple Choice* A special cell has an intracellular Na<sup>+</sup> concentration of 1 mM and an extracellular Na<sup>+</sup> concentration of 100 mM, while it has an intracellular Cl<sup>-</sup> concentration of 100mM and an extracellular Cl<sup>-</sup> concentration of 1 mM. Assuming the resting membrane potential is the same as a typical human cell, which of the following would occur if the Na<sup>+</sup> channels are opened and if the Cl<sup>-</sup> channels are opened in this cell, respectively?

- W) Depolarization, depolarization
- X) Depolarization, hyperpolarization
- Y) Hyperpolarization, depolarization
- Z) Hyperpolarization, hyperpolarization

ANSWER: W) DEPOLARIZATION, DEPOLARIZATION [KD]

## TOSS-UP

15. Physics *Multiple Choice* Emmy accidentally flipped a switch on the universal control panel, and now gravity exerts a force proportional to r and not  $1/r^2$ . Which of the following is no longer true about 2-body systems?

- W) They have five Lagrange points
- X) Angular momentum is conserved
- Y) Orbits can be any conic
- Z) Orbits are always periodic

ANSWER: Y) ORBITS CAN BE ANY CONIC [SC]

### BONUS

15. Physics *Short Answer* A Hookean spring is relaxed, and then chopped unevenly into four pieces with lengths in a 1:2:3:4 ratio. These pieces are then placed in parallel to form a composite spring. What is the ratio of the spring constant of this new composite spring to the original spring?

ANSWER: 125/6 [SC]

### TOSS-UP

16. Chemistry *Short Answer* Identify all of the following three alkene addition reactions that proceed via a carbocation [**car-bo-CAT-ion**] intermediate:

- 1) Oxymercuration
- 2) Hydroboration
- 3) Hydrogenation

ANSWER: NONE [YL]

### BONUS

16. Chemistry *Multiple Choice* Consider the reaction between **A** and **B** to form **C** and **D**. If the enthalpy change of the reaction is -300 kilojoules per mole and the entropy change is 80 joules per mole kelvin, at what temperature is this reaction at equilibrium?

- W) 3.75 K
- X) 375 K
- Y) 3750 K
- Z) The reaction is never at equilibrium

ANSWER: Z) THE REACTION IS NEVER AT EQUILIBRIUM [YL]

### TOSS-UP

17. Math *Multiple Choice* Yunyi is asked to determine the number of jelly beans in a jar. Every guess, he is told if his guess is over or under the actual number. If he starts by guessing 10

million, and is told his guess is over, what is the maximum number of subsequent guesses he would need to guess the number of jelly beans?

- W) 21
- X) 22
- Y) 23
- Z) 24

ANSWER: Z) 24 [EZ]

### BONUS

17. Math *Short Answer* A calculator has two buttons. It can add 1 to the displayed number or multiply it by 3. If the calculator currently displays 10, what is the least number of button presses to make it display 1000?

ANSWER: 8 [EZ]

### TOSS-UP

18. Earth and Space *Multiple Choice* The Fermi lobes of the Milky Way are **not** notably bright in which of the following bands of the electromagnetic spectrum?

- W) Gamma-ray
- X) X-ray
- Y) Visible
- Z) Radio

ANSWER: Y) VISIBLE [SC]

### BONUS

18. Earth and Space *Short Answer* In the Northern Hemisphere, a wind blowing due east across the ocean generates an Ekman spiral. At the bottom of the spiral, in what cardinal direction is the water flowing?

ANSWER: WEST [KW]

### TOSS-UP

19. Biology *Short Answer* Identify all of the following 3 types of white blood cells that are granular:

- 1) Eosinophils

- 2) T Lymphocytes
- 3) B Lymphocytes

ANSWER: 1 ONLY [KD]

**BONUS**

19. Biology *Short Answer* The tail length trait in a certain type of alien triploid orca exhibits polygenic inheritance and is under the control of 5 different genes. If each dominant allele adds 1 inch to the tail length of the orca, how many different tail lengths can an orca obtain?

ANSWER: 16 [KD]

**TOSS-UP**

20. Physics *Multiple Choice* A vase is dropped from a height  $H$  and its pieces scatter into a circle of radius  $r$ . If the vase were instead dropped from a height  $2H$ , what would the radius of the corresponding debris circle be?

- W)  $r$
- X)  $\sqrt{2} r$
- Y)  $2r$
- Z)  $4r$

ANSWER: Y)  $2R$  [SC]

**BONUS**

20. Physics *Multiple Choice* Yunyi has attached his collection of textbooks to his spaceship with infinite fuel. However, this shifts the ship's center of mass, causing its engine to produce a torque. If the engine cannot be shut down, which of the following describes his velocity and angular velocity after a long time, ignoring relativity?

- W) Constant, constant
- X) Constant, Infinite
- Y) Infinite, constant
- Z) Infinite, Infinite

ANSWER: X) CONSTANT, INFINITE [SC]

**TOSS-UP**

21. Chemistry *Short Answer* Identify all of the following three compounds that are NOT miscible with water:

- 1) Methanol
- 2) Hexane
- 3) Ethyl acetate

ANSWER: 2 AND 3 [YL]

### BONUS

21. Chemistry *Multiple choice* Which of the following electrolysis reactions would NOT require an inert electrode?

- W)  $2\text{HCl}(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{Cl}_2(\text{g})$  [**2 HCl aqueous yields H<sub>2</sub> gas plus Cl<sub>2</sub> gas**]  
X)  $2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$  [**2 H<sub>2</sub>O liquid yields 2 H<sub>2</sub> gas plus O<sub>2</sub> gas**]  
Y)  $\text{Zn}^{2+}(\text{aq}) + 2\text{Ag}(\text{s}) \rightarrow \text{Zn}(\text{s}) + 2\text{Ag}^+(\text{aq})$  [**Zn<sup>2+</sup> aqueous plus 2 Ag solid yields Zn solid plus 2 Ag<sup>+</sup> aqueous**]  
Z)  $\text{Pb}^{4+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Pb}^{2+}(\text{aq}) + 2\text{Fe}^{3+}(\text{aq})$  [**Pb<sup>4+</sup> aqueous plus 2 Fe<sup>2+</sup> aqueous yields Pb<sup>2+</sup> aqueous plus 2 Fe<sup>3+</sup> aqueous**]

ANSWER: Y)  $\text{Zn}^{2+}(\text{aq}) + 2\text{Ag}(\text{s}) \rightarrow \text{Zn}(\text{s}) + 2\text{Ag}^+(\text{aq})$  [YL]

### TOSS-UP

22. Math *Short Answer* Anurag is playing rock paper scissors versus a robotic arm. What is the probability Anurag wins if the arm picks randomly between rock paper and scissors and Anurag goes rock 20% of the time, paper 30% of the time, and scissors 50% of the time?

ANSWER: 1/3 [EZ]

### BONUS

22. Math *Multiple Choice* What is the remainder when  $2024^{2024}$  is divided by 17?

- W) 1  
X) 2  
Y) 3  
Z) 4

ANSWER: W) 1 [EZ]

### TOSS-UP

23. Earth and Space *Multiple Choice* The channeled scablands in Washington state were carved by flash floods after the retreat of a glacier that had confined a lake just beyond its terminus. Which of the following adjectives best describes this lake?

- W) Pluvial
- X) Subglacial
- Y) Proglacial
- Z) Finger

ANSWER: Y) PROGLACIAL [KW]

### BONUS

23. Earth and Space *Short Answer* Which of the following three sand formations would likely only be found in areas without much vegetation?

- 1) Parabolic dunes
- 2) Blowouts
- 3) Ventifacts

ANSWER: 3 ONLY [SC]

### TOSS-UP

24. Biology *Short Answer* 2D gel electrophoresis, a common method for purifying proteins, separates the samples by mass and what other characteristic?

ANSWER: ISOELECTRIC POINT [KD]

### BONUS

24. Biology *Multiple Choice* A sample of cells from the procambium of a growing plant is dyed. In which of the following cells would you most likely see this dye as the plant matures?

- W) Tracheid (*TRAY-kee-id*)
- X) Epidermis
- Y) Cork cell
- Z) Parenchyma cell

ANSWER: W) TRACHEID [KD]

### TOSS-UP

25. Physics *Short Answer* Identify all of the following three pairs of physical quantities that are conjugate operators:

- 1) Energy and time
- 2) Position and momentum

3) Orientation and angular momentum

ANSWER: ALL [YL]

**BONUS**

25. Physics *Multiple Choice* Michael stands on a tower and spins a volleyball about some horizontal axis. He notes that after dropping the volleyball with this spin, it accelerates horizontally back into the tower. Which of the following best describes the direction of the volleyball's angular velocity vector, from Michael's perspective?

- W) Forward
- X) To the right
- Y) Backward
- Z) To the left

ANSWER: Z) TO THE LEFT [SC]