

High School  
Set 1

TOSS-UP

1) Energy – *Short Answer* Scientists at Fermi National Lab are studying the decay modes of the lightest group of mesons. What is the name of this group of 3 particles?

ANSWER: PIONS (ACCEPT: PI MESONS)

BONUS

1) Energy – *Short Answer* Researchers at Los Alamos National Lab are studying the effects of Super El Nino events in the past, including the one that occurred from 2015 to 2016. Identify all of the following three changes that are consequences of an El Nino event:  
1) Increases in soil moisture in India; 2) High air pressure in the Western Pacific; 3) High sea surface temperatures off the coast of Peru.

ANSWER: 2 AND 3

## TOSS-UP

2) Math – *Multiple Choice* In the prime factorization of a perfect square, the exponents of the prime factors must be which of the following types of numbers?

- W) Even
- X) Odd
- Y) Prime
- Z) Perfect squares

ANSWER: W) EVEN

## BONUS

2) Math – *Short Answer* A right circular cylinder has height 15 and diameter 18. What is its surface area?

ANSWER:  $432\pi$

## TOSS-UP

3) Physics – *Multiple Choice* Which of the following best describes the volume of a 10-gram sample of water as a function of temperature?

- W) Linearly increasing from 0 to 100 degrees Celsius
- X) Linearly decreasing from 0 to 100 degrees Celsius
- Y) Non-linear with a local maximum at 4 degrees Celsius
- Z) Non-linear with a local minimum at 4 degrees Celsius

ANSWER: Z) NON-LINEAR WITH A LOCAL MINIMUM AT 4 DEGREES CELSIUS

## BONUS

3) Physics – *Short Answer* Lightning strikes a lightning rod on a building that is 3 kilometers away from you. To the nearest whole second, how long will it take the sound of the thunder to reach you?

ANSWER: 9

## TOSS-UP

4) Biology – *Short Answer* What vitamin is essential in humans for the synthesis of several blood clotting factors?

ANSWER: K (ACCEPT: PHYLLLOQUINONE, MENAQUINONE, PHYTOMENADIONE, K1, K2)

## BONUS

4) Biology – *Multiple Choice* Coronaviruses are positive-sense single-stranded RNA viruses. Which of the following describes how their genetic material is processed after entering a cell?

- W) Transcribed to mRNA with RNA-dependent RNA polymerase  
*[pah-LIM-er-ace]*
- X) Directly translated by host ribosomes
- Y) Reverse transcribed to DNA with reverse transcriptase
- Z) Translated after assembly of viral ribosomes

ANSWER: X) DIRECTLY TRANSLATED BY HOST RIBOSOMES

## TOSS-UP

5) Chemistry – *Short Answer* What is the value of the reaction quotient when the change in Gibbs free energy is zero?

ANSWER: K (ACCEPT: EQUILIBRIUM CONSTANT)

## BONUS

5) Chemistry – *Short Answer* Match the flame test colors blue, green, and purple to the following three metals or compounds:  
1) Boric acid; 2) Potassium; 3) Cesium.

ANSWER: 1) GREEN; 2) PURPLE; 3) BLUE (ACCEPT: BORIC ACID IS GREEN, POTASSIUM IS PURPLE, CESIUM IS BLUE)

## TOSS-UP

6) Earth and Space – *Short Answer* Jet streams are located at what boundary in Earth's atmosphere?

ANSWER: TROPOPAUSE

## BONUS

6) Earth and Space – *Short Answer* Speleothem  
***[SPEEL-ee-o-them]*** cave deposits are most typically composed of what type of rock?

ANSWER: LIMESTONE

## TOSS-UP

7) Energy – *Short Answer* Scientists supported by the Department of Energy are developing new ways to synthesize carbon fiber. In carbon fiber, what is the hybridization state of the carbon atoms?

ANSWER: SP2

## BONUS

7) Energy – *Short Answer* Scientists supported by the Department of Energy are producing catalysts for methanol production. They are synthesizing methanol via the oxidation of what organic starting material?

ANSWER: METHANE

## TOSS-UP

8) Math – *Short Answer* If  $f$  is a continuous function such that the definite integral from 4 to 8 of  $f$  of  $x$   $dx$  equals 24, what is the average value of  $f$  on the closed interval from 4 to 8?

ANSWER: 6

## BONUS

8) Math – *Short Answer* If the product of cosine  $x$  and sine  $x$  is  $-1/6$ , what is the value of open parenthesis cosine  $x$  minus sine  $x$  close parenthesis squared?

ANSWER:  $4/3$  (ACCEPT:  $1 \frac{1}{3}$ )



## TOSS-UP

9) Physics – *Short Answer* J.J. Thomson won the Nobel Prize in Physics for calculating the charge-to-mass ratio of what particles in cathode rays?

ANSWER: ELECTRONS

## BONUS

9) Physics – *Short Answer* The  $x$ -component and the  $y$ -component of an object's velocity are both 5 meters per second. In meters per second, what is the speed of this object?

ANSWER:  $5\sqrt{2}$

## TOSS-UP

10) Biology – *Short Answer* Ducks have webbed feet while chickens do not. This morphogenetic difference is mediated by BMP4 and Gremlin, which are proteins involved in what cellular process?

ANSWER: APOPTOSIS

## BONUS

10) Biology – *Short Answer* Identify all of the following three compounds that are derivatives of cholesterol: 1) Testosterone; 2) Cortisol; 3) Retinol.

ANSWER: 1, 2

## TOSS-UP

11) Chemistry – *Multiple Choice* Kate is performing an experiment where she has a chamber containing an inert gas. The chamber is at a fixed temperature and she varies the pressure of the chamber. She generates a curve by plotting pressure on the  $x$ -axis and  $PV$  over  $RT$  on the  $y$ -axis. At which of the following fixed chamber temperatures, in kelvins, would this curve be the MOST linear?

- W) 250
- X) 500
- Y) 1000
- Z) 1500

ANSWER: Z) 1500

## BONUS

11) Chemistry – *Short Answer* Identify all of the following four acids that are considered weak acids: 1) HF; 2)  $\text{CH}_3\text{COOH}$ ; 3) HCN; 4)  $\text{H}_3\text{PO}_4$ .

ANSWER: ALL



TOSS-UP

12) Earth and Space – *Short Answer* What is the name for the gap between Saturn's A and B rings?

ANSWER: CASSINI DIVISION (ACCEPT: CASSINI)

BONUS

12) Earth and Space – *Multiple Choice* In kelvins, which of the following is closest to the radiative equilibrium temperature of Earth?

- W) 100
- X) 250
- Y) 300
- Z) 350

ANSWER: X) 250

## TOSS-UP

13) Energy – *Short Answer* Argonne National Lab researchers are studying photocatalysts made of  $\text{Cu}_2\text{O}$  to reduce carbon dioxide into methanol. What is the IUPAC [*EYE-you-pack*] name for  $\text{Cu}_2\text{O}$ ?

ANSWER: COPPER (I) OXIDE (do not accept: CUPROUS OXIDE)

## BONUS

13) Energy – *Short Answer* Scientists at SLAC National Accelerator Facility are studying photo-iso-mer-i-zation in opsins. Identify all of the following three statements that are true of opsins: 1) They are G-protein-coupled receptors; 2) They are found in the retina; 3) They are covalently bound to retinal [*REHT-nul*] when active.

ANSWER: ALL

## TOSS-UP

14) Math – *Short Answer* What is the discriminant of the quadratic polynomial  $8x^2 + 7x - 2$ ?

ANSWER: 113

## BONUS

14) Math – *Short Answer* Lloyd is asked by his teacher to subtract 4 from a number and multiply the result by 2. Instead, he subtracts 2 and then multiplies the result by 4, giving him 124. What is the correct answer to the teacher's question?

ANSWER: 58

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## TOSS-UP

15) Physics – *Multiple Choice* Which of the following are the units of entropy?

- W) Joules
- X) Newtons per kelvin
- Y) Watts
- Z) Joules per kelvin

ANSWER: Z) JOULES PER KELVIN

## BONUS

15) Physics – *Short Answer* A car starting at rest undergoes a constant acceleration of 16 meters per second squared. In meters per second, what is the speed of the car after it has traveled half a meter?

ANSWER: 4

## TOSS-UP

16) Biology – *Short Answer* What chromosome are Barr bodies derived from?

ANSWER: X

## BONUS

16) Biology – *Multiple Choice* In eukaryotic cells, the electron transport chain directly performs which of the following actions?

- W) Generating ATP
- X) Generating GTP
- Y) Pumping protons into the mitochondrial matrix
- Z) Pumping protons into the intermembrane space

ANSWER: Z) PUMPING PROTONS INTO THE INTERMEMBRANE SPACE



## TOSS-UP

17) Chemistry – *Short Answer* What principle states that two electrons cannot have the same quantum numbers?

ANSWER: PAULI EXCLUSION PRINCIPLE

## BONUS

17) Chemistry – *Multiple Choice* Which of the following statements is true regarding the energetics of electrochemical cells?

- W) For a voltaic cell, E-cell is positive and delta G is positive
- X) For a voltaic cell, E-cell is positive and delta G is negative
- Y) For an electrolytic cell, E-cell is negative and delta G is negative
- Z) For an electrolytic cell, E-cell is positive and delta G is negative

ANSWER: X) FOR A VOLTAIC CELL, E-CELL IS POSITIVE AND DELTA G IS NEGATIVE

## TOSS-UP

18) Earth and Space – *Short Answer* In what phase is the Moon when moonrise occurs at noon?

ANSWER: FIRST QUARTER

## BONUS

18) Earth and Space – *Multiple Choice* Which of the following types of stars has a luminosity [*loo-min-AW-sih-tee*] most similar to that of red dwarfs?

- W) Red giants
- X) Yellow dwarfs
- Y) White dwarfs
- Z) Brown dwarfs

ANSWER: Y) WHITE DWARFS