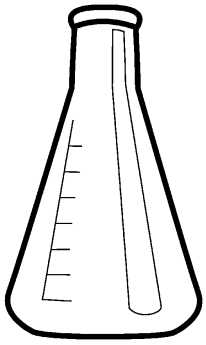
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

District • 2019



GENERAL DIRECTIONS:

- DO NOT OPEN EXAM UNTIL TOLD TO DO SO.
- Contestants may take up to two hours to complete the contest. If you are in the process of actually writing an answer when the signal to stop is given, you may finish writing that answer.
- Papers may not be turned in until 30 minutes have elapsed. If you finish the test in less than 30 minutes, remain at your seat and retain your paper until told to do otherwise. You may use this time to check your answers.
- All answers must be written on the answer sheet provided. Indicate your answers in the appropriate blanks provided on the answer sheet. Write clearly and legibly!
- You may place as many notations as you desire anywhere on the test paper but not on the answer sheet, which is reserved for answers only.
- You may use additional scratch paper provided by the contest director.
- All questions have ONE and only ONE correct (BEST) answer. There is a penalty for all incorrect answers.
- If a question is omitted, no points are given or subtracted.
- The back two pages of this test include a copy of the periodic table of the elements, as well as listings of other scientific relationships. You may use this information during the contest and may detach the back page from the test if you wish.
- A simple scientific calculator is sufficient for the high school Science contest. **The UIL provides a list of approved calculators that meet the criteria for use in the Science contest. No other calculators are permitted during the contest.** The Science Contest Approved Calculator List is available in the current Science Contest Handbook and on the UIL website. Contest directors will perform a brief visual inspection to confirm that all contestants are using only approved calculators. Each contestant may use up to two approved calculators during the contest.

B01. A researcher determined that an unknown cell type contained the following features:

80S ribosomes
Cellulose in the cell wall
Photosynthetic pigments

This cell type likely belongs to
A) Domain Eukarya.
B) Domain Prokarya.
C) Domain Bacteria.
D) Domain Archaea.
E) Unable to determine from the information given.

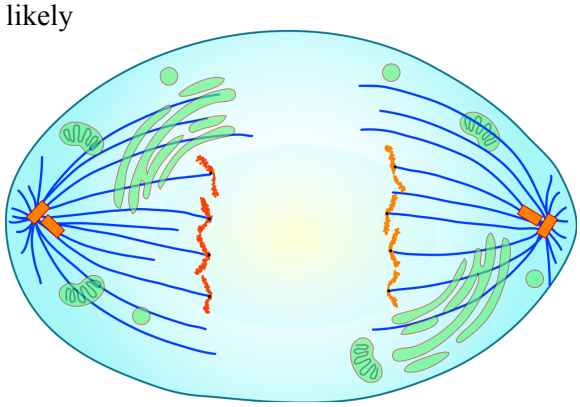
B02. Mendelian inheritance patterns rely on several principles. Which of the following is not a principle of Mendelian genetics?
A) Parental traits are blended in the offspring.
B) Traits are controlled by a single locus.
C) Discrete units of inheritance are passed from parents to offspring.
D) Alleles for a trait are separated during gamete production and randomly reunite during fertilization.
E) Genes located on different chromosomes are inherited independently of each other.

B03. Which DNA technology includes a guide RNA (gRNA) and nuclease and has proven to be a powerful and incredibly specific genome editing tool in recent years?
A) agarose gel electrophoresis
B) transformation
C) CRISPR/Cas
D) restriction enzyme digestion
E) PCR

B04. If a cell does not receive a signal to progress into the next phase during the _____ checkpoint, the cell could enter a nondividing phase called G_0.
A) mitosis
B) G_1
C) G_2
D) metaphase
E) S

B05. A gymnosperm
A) is non-vascularized.
B) is usually a deciduous plant.
C) produces flowers.
D) produces unenclosed, or "naked," seeds.
E) has flat, broad leaves.

B06. The mitotic stage observed in this image is most likely



A) interphase
B) prophase
C) metaphase
D) anaphase
E) telophase

B07. The Cretaceous-Tertiary (K-T) boundary is a geological feature (a thin banding in rock) that marks the end of the Cretaceous Period and the beginning of the Paleogene Period. The banding likely formed from a meteorite impact occurring approximately 66 million years ago. If the fossil record was accurately recorded above and below this line, which specific group of organisms would you not expect to find in high biodiversity below the K-T boundary?
A) invertebrates
B) angiosperms
C) reptiles
D) dinosaurs
E) mammals

B08. The role a species plays in its environment and the set of abiotic and biotic conditions in which a species is able to persist and maintain a stable population size is termed
A) niche.
B) biome.
C) biosphere.
D) habitat.
E) community.

B09. The organ system that includes the esophagus, stomach, and intestines is called the _____ system.
A) respiratory
B) cardiovascular
C) nutrient
D) lymphatic
E) digestive

B10. A gene encoded on a segment of DNA contains all of the necessary sequences to direct protein synthesis. Which of the following sequences, when bound by an appropriate regulatory molecule, would repress transcription?
A) promoter
B) operator
C) start codon
D) ribosomal binding site
E) transcriptional terminator

B11. As of January 2019, the CDC and other public health officials were investigating an outbreak of ___ _____ from pet hedgehogs.
A) *Salmonella* Typhi
B) *Shigella dysenteriae*
C) *Salmonella* Typhimurium
D) *Escherichia coli* O157:H7
E) *Staphylococcus aureus*

B12. A scientific name provides information on the _____ of the organism.
A) phylum and class
B) genus only
C) genus and species
D) kingdom
E) phylum

B13. A catabolic pathway that transfers electrons from NADH to pyruvate, and subsequently produces ethanol and carbon dioxide, would most specifically be called
A) glycolysis.
B) pyruvate oxidation.
C) lactic acid fermentation.
D) alcohol fermentation.
E) Electron Transport Chain.

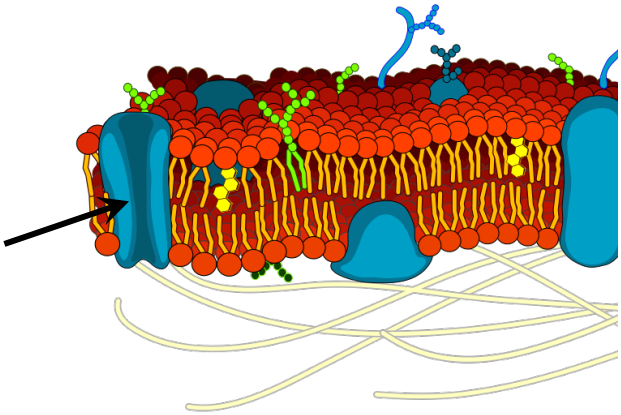
B14. The type of nervous system cell that transmits electrochemical impulses is called the
A) glial cell.
B) neuron.
C) Schwann cell.
D) astrocyte.
E) oligodendrocyte.

B15. During aerobic respiration, glucose is catabolized through a series of steps to produce two pyruvates. In the next step, each pyruvate is oxidized to produce _____ and a reduced high energy electron carrier molecule.
A) glucose
B) acetyl-CoA and carbon dioxide
C) NAD^+
D) oxygen
E) citrate

B16. In terms of trophic levels, an organism that is a herbivore would also be called a
A) secondary consumer.
B) tertiary consumer.
C) quaternary consumer.
D) primary producer.
E) primary consumer.

B17. What feature do both Kingdom Animalia and Kingdom Plantae have in common?
A) cell walls
B) tissue vascularization
C) heterotrophic
D) eukaryotic
E) chloroplast

B18. In this image, the arrow is pointing to a



A) glycolipid.
B) glycoprotein.
C) cholesterol.
D) phospholipid.
E) transmembrane protein.

B19. Which of the following has no vaccine available to the human population?
A) Measles
B) Mumps
C) HIV
D) HPV
E) Chickenpox

B20. The process of translation
A) synthesizes a protein's primary structure.
B) generates ribosomal RNA sequences.
C) occurs within the nucleus of eukaryotic cells.
D) transmits genetic information to an RNA intermediary.
E) covalently links nucleotides to form a polymer.

C01. What can you say about an atom that has the electron configuration $1s^2 2s^2 2p^5 3s^1$?

A) It has absorbed energy from its surroundings.
B) It forms one single bond with other atoms.
C) It is an anion.
D) It is a cation.
E) It is an alkali metal.

C02. Arrange these compounds in order of increasing melting point: BaS, KCl, LiF, NaCl, CaO

A) CaO < BaS < LiF < KCl < NaCl
B) NaCl < KCl < LiF < BaS < CaO
C) LiF < NaCl < KCl < CaO < BaS
D) BaS < CaO < KCl < NaCl < LiF
E) KCl < NaCl < LiF < BaS < CaO

C03. 4.65 mol of a metal oxide has a mass of 712.98 g. Which compound is it?

A) MoO_3
B) SnO_2
C) Cr_2O_3
D) BaO
E) Fe_2O_3

C04. What is the sum of the coefficients in the balanced redox reaction when Au^{3+} and I^- react in solution to form elemental products?

A) 5
B) 6
C) 8
D) 9
E) 13

C05. 3.45 g Na is added to a 2.5 L container containing 744 torr of Cl_2 gas at 25°C, then a small amount of water is added to initiate the reaction. Assuming the reaction goes to completion, what is the mass of NaCl formed?

A) 5.84 g
B) 6.38 g
C) 6.97 g
D) 8.77 g
E) 11.7 g

C06. In a mixture of two different ideal gases, particles with different masses will have

A) The same average kinetic energy and the same root mean square velocity.
B) The same average kinetic energy, but different root mean square velocities.
C) Different average kinetic energies, but the same root mean square velocity.
D) Different average kinetic energies and different root mean square velocities.
E) Answers A and B are both possible depending on the nature of the two gases.

C07. If you drop a piece of potassium metal into water the following exothermic reaction occurs:

$$2\ K(s) + 2\ H_2O(\ell) \rightarrow 2\ KOH(aq) + H_2(g)$$

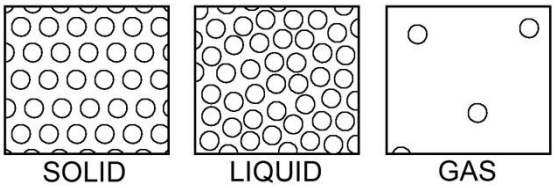
What are the values of q and w for this reaction, at constant temperature and pressure?

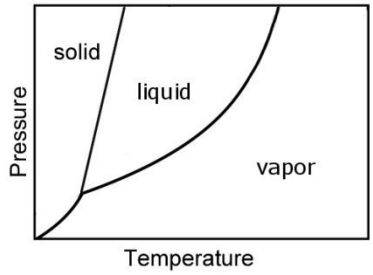
A) q is positive and w is negative.
B) q is negative and w is positive.
C) q and w are both negative.
D) q and w are both positive.
E) There is not enough information given.

C08. A 10.0 mL sample of a sulfuric acid solution of unknown concentration is diluted to 25.0 mL and then titrated to the phenolphthalein endpoint using 35.88 mL of 0.155 M NaOH. What is the concentration of the sulfuric acid solution?

A) 0.111 M
B) 0.222 M
C) 0.278 M
D) 0.444 M
E) 0.556 M

C09. Which of the phase diagrams below best corresponds to the compound shown here?



A)


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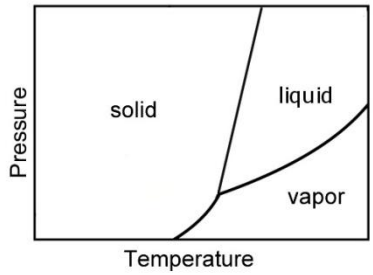

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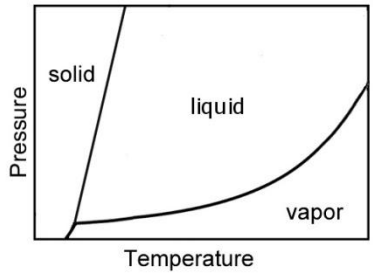
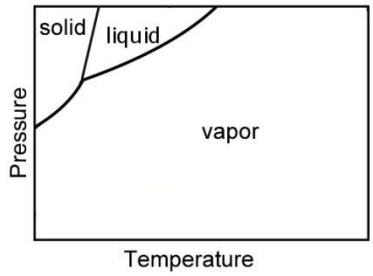
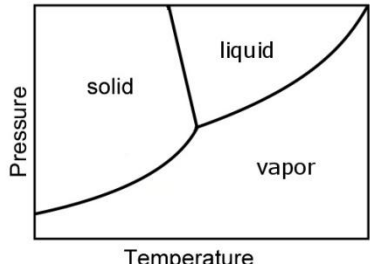


D)


E)


C10. A careless lab assistant misreads the labels on two bottles, and thinking they contain the same reagent, adds 100 mL of 0.50 M $AlCl_3$ to 250 mL of 0.50 M $AgClO_3$. What is the final silver ion concentration in the mixed solution?

A) 2.5×10^{-9} M
B) 1.3×10^{-5} M
C) 8.4×10^{-5} M
D) 0.33 M
E) 0.071 M

C11. If the electronic geometry of a molecule is trigonal bipyramidal and the central atom has three lone pairs of electrons, what is the shape of the molecule?

A) Linear
B) Bent
C) Trigonal bipyramidal
D) Square planar
E) Tetrahedral

C12. A 21.75 g sample of an unknown compound is found to contain 5.53 g of Na and 8.53 g of Cl. Which of these compounds is it most likely to be?

A) NaCl
B) NaClO
C) $NaClO_2$
D) $NaClO_3$
E) $NaClO_4$

C13. A student adds 10 mL of 1.0 M NaCl to 50 mL of 0.10 M $Pb(NO_3)_2$ and a white precipitate forms. The student dries and weighs the product and records a mass of 1.53 g. What is the most likely source of the error?

A) The student transposed two digits when writing down the mass.
B) Some product was lost during handling.
C) The product is not fully dry.
D) The reaction did not go to completion.
E) The bottle labeled NaCl was actually a different reagent with a higher molar mass, such as NaBr.

C14. A rich eccentric chemist creates an electrochemical cell using a solid silver anode in 1.0 M $AgNO_3$ and a solid gold anode in 1.0 M $AuNO_3$. When he completes the circuit, what will the standard potential of his cell be?

A) 2.63 V
B) –2.63 V
C) 1.03 V
D) –1.03 V
E) 0 V because neither metal will be oxidized.

C15. Methane gas reacts in a gas-phase equilibrium reaction with water vapor to form carbon monoxide and hydrogen gas. If a reaction chamber contains a reaction mixture that is already at equilibrium, what will happen if the volume of the container is increased at constant temperature?

A) The reaction will shift to the left.
B) The reaction will shift to the right.
C) There will be no change.
D) Initially the reaction will shift to the left, but then it will settle back to the same concentrations that were present before the volume increase.
E) Initially the reaction will shift to the right, but then it will settle back to the same concentrations that were present before the volume increase.

C16. For the reaction A + 2 B → C, a series of experiments were carried out using different initial concentrations of A and B to determine the rate law for the reaction. Given the data below:

Experiment	$[A]_0$	$[B]_0$	Initial rate (M/min)
1	2.0	3.0	0.1852
2	2.0	6.0	0.3709
3	4.0	3.0	0.7411

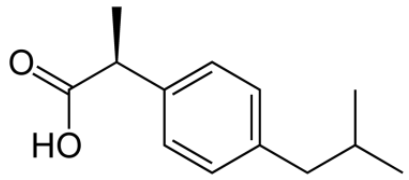
What is the rate law for the reaction?

A) rate = $k[A][B]$
B) rate = $k[A][B]^2$
C) rate = $k[A]^2[B]^3$
D) rate = $k[B]^2$
E) rate = $k[A]^2[B]$

C17. Engineers sometimes work using degrees Rankine (°R), which is an absolute temperature scale like the Kelvin scale but each degree is equal in size to a Fahrenheit degree. What is the boiling point of water in °R?

A) 212.00
B) 373.15
C) 478.55
D) 576.27
E) 671.67

C18. What is the molar mass of ibuprofen, also known by the trade names Advil and Motrin, shown below?



A) 164.22 g/mol
B) 189.14 g/mol
C) 206.31 g/mol
D) 228.63 g/mol
E) None of these

C19. How many sp^3 hybridized carbon atoms are in the ibuprofen molecule shown in question C18?

A) 0
B) 4
C) 6
D) 7
E) 13

C20. If 78.8 g of AgI is added to 630.0 mL of 0.45 M FeI_3 and the solution is diluted to 1.00 L, what will the iodide concentration in the final solution be? (AgI $K_{sp} = 8.52 \times 10^{-17}$).

A) 0.19 M
B) 0.28 M
C) 0.36 M
D) 0.85 M
E) 1.0 M

P01. According to Natarajan, _____ was the first astronomer to attempt to derive a physical theory that would explain and describe the motions of the planets.
A) Kepler
B) Copernicus
C) Brahe
D) Galileo
E) Newton

P02. According to Natarajan, the theory developed by George Gamow that described the primordial soup of particles in the early universe was criticized for failing to predict…
A) the homogeneity of the universe.
B) the existence of dark matter.
C) the correct age of the universe.
D) the expansion of the universe.
E) the formation of elements beyond H and He.

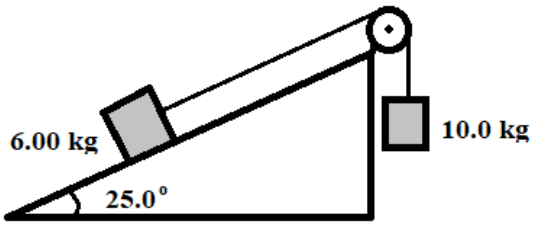
P03. According to Natarajan, Fritz Zwicky first proposed the existence of dark matter after observing the motions of…
A) stars in the galactic halo.
B) stars near the galactic core.
C) galaxies in the local group.
D) galaxies in the Coma Cluster.
E) comets around the Sun.

P04. Heat transfer from the core of the Sun to the outer layers of the Sun occurs primarily by…
A) Conduction
B) Convection
C) Radiation
D) Friction
E) Fusion

P05. A cylinder of metal has a radius of 1.314 cm and a length of 2.86 cm. The density of the cylinder is 8.6 g/cm^3. To the correct number of significant digits, what is the mass of the cylinder?
A) 100 g
B) 130 g
C) 133 g
D) 133.4 g
E) 133.42 g

P06. A truck is travelling at 32.0m/s along a straight highway. It accelerates at -2.78m/s^2 for 8.00sec. How far did the truck travel while it was accelerating?
A) 434 m
B) 345 m
C) 256 m
D) 167 m
E) 78.1 m

P07. An Atwood machine is set up using a frictionless incline (as shown). The angle of the incline is 25.0° and the pulley is massless and frictionless. What is the acceleration of the blocks?

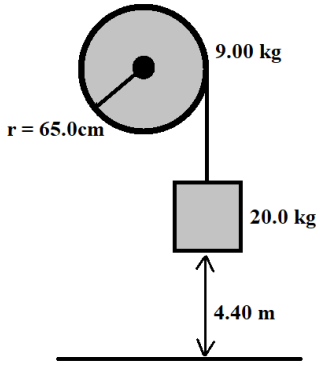


A) 1.98 m/s^2
B) 2.45 m/s^2
C) 4.57 m/s^2
D) 5.66 m/s^2
E) 7.68 m/s^2

P08. An acrobat with a mass of 70.0kg is dangling at rest from a long rope. A second acrobat with a mass of 60.0kg is flying horizontally with a speed of 12.50m/s when she grabs onto the first acrobat. Together, the acrobats swing up like a pendulum. How high above the point of their collision do the acrobats swing up to?
A) 1.70 m
B) 2.31 m
C) 3.40 m
D) 5.86 m
E) 7.97 m

P09. For the pulley setup shown, the hanging mass is 20.0kg, and the pulley is a solid disk with a mass of 9.00kg and a radius of 65.0cm. The hanging mass is released 4.40m above the floor, and the rope unwinds from the pulley without slipping. What is the rotational speed of the pulley when the mass reaches the floor? The moment of inertia of a solid disk is given by the formula $I = \frac{1}{2}mr^2$.

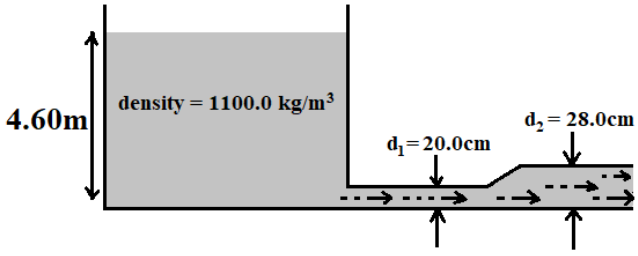
A) 8.39 rad/s
B) 9.29 rad/s
C) 12.9 rad/s
D) 14.3 rad/s
E) 19.6 rad/s



P10. A trombone is a musical instrument formed from a wrapped, adjustable open-open pipe. For a particular slide position (at 20°C), the seventh resonance is at 512 Hz. For that position, what is the length of the pipe that forms the trombone?

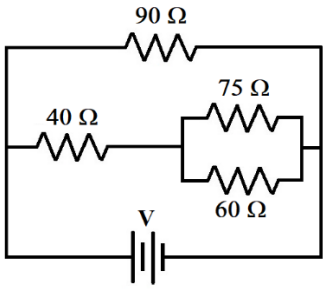
A) 1.17 m
B) 2.18 m
C) 2.34 m
D) 4.35 m
E) 5.22 m

P11. For the ideal fluid flow system shown, determine the velocity of the fluid in the smaller pipe. The fluid in the reservoir tank is 4.60m deep and the reservoir is open to air. The diameters of the pipes are 20.0cm and 28.0cm, respectively, and the larger pipe opens to air at the end, emptying the fluid into a pond. The density of the fluid is 1100.0 kg/m^3.



A) 4.84 m/s
B) 6.78 m/s
C) 9.50 m/s
D) 13.3 m/s
E) 18.6 m/s

P12. In this circuit, the voltage across the 75 Ω resistor is 3.50V. Calculate the voltage supplied by the battery.

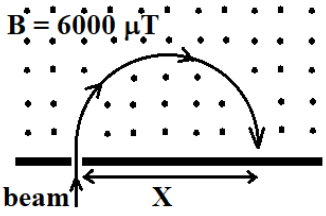


A) 4.2 V
B) 7.7 V
C) 9.5 V
D) 11 V
E) 19 V

P13. A charge of 610nC is located on the y-axis at (0.0, 4.50cm), and a charge of −470nC is located on the x-axis at (3.00cm, 0.0). What is the magnitude of the electric field at the origin (0.0, 0.0) due to these charges?

A) 1.99×10^6 N/C
B) 2.71×10^6 N/C
C) 4.69×10^6 N/C
D) 5.42×10^6 N/C
E) 7.40×10^6 N/C

P14. A beam of singly-ionized ions enters a mass spectrometer with a velocity of 7500.0m/s. The magnetic field strength in the spectrometer is 6000.0 μT, and the ions are detected at X = 62.0cm (as shown). What is the mass of one of these ions in atomic mass units?



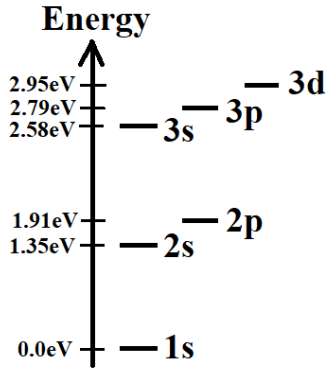
A) 23.9 amu
B) 37.4 amu
C) 47.9 amu
D) 54.6 amu
E) 95.7 amu

P15. A laser beam has a radius of 3.00mm and a peak electric field of 500.0N/C. What is the average power of the laser?
A) 39.9 mW
B) 28.2 mW
C) 18.8 mW
D) 13.3 mW
E) 9.40 mW

P16. A flower is placed 12.0cm in front of a convex mirror with a radius of curvature (magnitude) of 28.0cm. What is the magnification of the flower?
A) -1.25
B) -0.75
C) $+0.30$
D) $+0.54$
E) $+0.70$

P17. Selection rules are patterns that atoms generally follow during atomic transitions. The primary rule is that $\Delta\ell = \pm 1$. Transitions for which $\Delta\ell = 0$ or ± 2 are "forbidden." Use this main selection rule to determine which of the given wavelengths would be allowed to be emitted from atoms that have the following energy level diagram:

A) 775 nm
B) 919 nm
C) 1010 nm
D) 1190 nm
E) 1410 nm

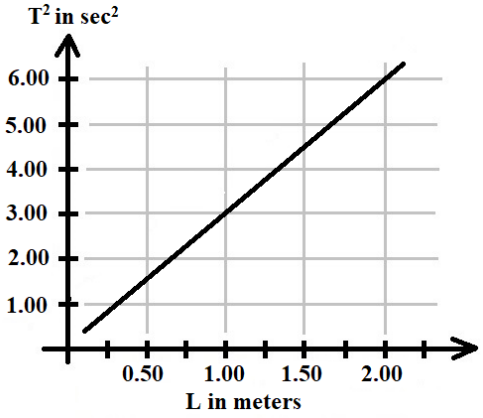


P18. In this strong-force particle interaction, which particle could go in the blank without violating any conservation laws?

$$p^+ + \pi^- \rightarrow n^0 + \_\_\_\_$$
[Proton + pion → neutron + _____]

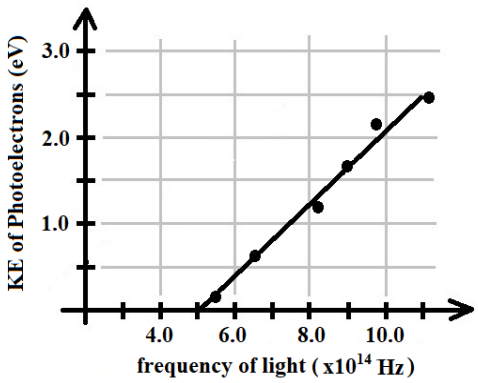
A) ρ^0 (rho-meson)
B) π^+ (pion)
C) K^0 (kaon)
D) Λ^0 (lambda)
E) μ^- (muon)

P19. While living on a habitable planet in another solar system, you measure the oscillation period (T) of a pendulum as a function of the length (L) of the pendulum. You obtain the following graph by plotting T^2 versus L. From this data, determine the gravitational acceleration on this alien world.



A) 18.8 m/s²
B) 13.1 m/s²
C) 6.58 m/s²
D) 4.19 m/s²
E) 2.09 m/s²

P20. The kinetic energy of the photoelectrons emitted from a metal surface is measured as a function of the frequency of light illuminating the surface. The data is graphed below. From this data, determine the workfunction of the metal surface.



A) 0.4 eV
B) 1.2 eV
C) 2.1 eV
D) 2.4 eV
E) 5.0 eV

Chemistry

1A 1												3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H 1.01	2A 2																2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3B 3	4B 4	5B 5	6B 6	7B 7	8	8B 9	10	1B 11	2B 12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.9	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (293)	118 Og (294)

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Water Data

T_{mp} = 0°C
T_{bp} = 100°C
c_{ice} = 2.09 J/g·K
c_{water} = 4.184 J/g·K
c_{steam} = 2.03 J/g·K
ΔH_{fus} = 334 J/g
ΔH_{vap} = 2260 J/g
K_f = 1.86 °C/*m*
K_b = 0.512 °C/*m*

Constants

$R = 0.08206$ L·atm/mol·K
$R = 8.314$ J/mol·K
$R = 62.36$ L·torr/mol·K
$e = 1.602 \times 10^{-19}$ C
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$k = 1.38 \times 10^{-23}$ J/K
$h = 6.626 \times 10^{-34}$ J·s
$c = 3.00 \times 10^{8}$ m/s
$R_H = 2.178 \times 10^{-18}$ J
$m_e = 9.11 \times 10^{-31}$ kg

K_{sp} values

AgCl	1.77×10^{-10}
AgI	8.52×10^{-17}
$PbCl_2$	1.70×10^{-5}

Standard Reduction Potentials

$Au^+(aq) + e^- \rightarrow Au(s)$ $E° = +1.83$
$Ag^+(aq) + e^- \rightarrow Ag(s)$ $E° = +0.80$

Physics

Useful Constants

quantity	symbol	value
Free-fall acceleration	g	$9.80\ m/s^2$
Permittivity of Free Space	ε_0	$8.854 \times 10^{-12}\ C^2/Nm^2$
Permeability of Free Space	μ_0	$4\pi \times 10^{-7}\ Tm/A$
Coulomb constant	k	$8.99 \times 10^{9}\ Nm^2/C^2$
Speed of light in a vacuum	c	$3.00 \times 10^{8}\ m/s$
Fundamental charge	e	$1.602 \times 10^{-19}\ C$
Planck's constant	h	$6.626 \times 10^{-34}\ Js$
Electron mass	m_e	$9.11 \times 10^{-31}\ kg$
Proton mass	m_p	$1.67265 \times 10^{-27}\ kg$
Neutron mass	m_n	$1.67495 \times 10^{-27}\ kg$
Atomic Mass Unit	amu	$1.66 \times 10^{-27}\ kg$
Gravitational constant	G	$6.67 \times 10^{-11}\ Nm^2/kg^2$
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ W/m^2K^4$
Universal gas constant	R	$8.314\ J/mol \cdot K$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ J/K$
Speed of Sound (at 20ºC)	v	343 m/s
Avogadro's number	N_A	$6.022 \times 10^{23}\ atoms/mol$
Electron Volts	eV	$1.602 \times 10^{-19}\ J/eV$
Distance Conversion	miles → meters	1.00 mile = 1609 meters
Rydberg Constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$
Standard Atmospheric Pressure	1 atm	$1.013 \times 10^{5}\ Pa$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2019 DISTRICT

Biology	Chemistry	Physics
B01. A	C01. A	P01. A
B02. A	C02. E	P02. E
B03. C	C03. D	P03. D
B04. B	C04. E	P04. C
B05. D	C05. D	P05. B
B06. D	C06. B	P06. D
B07. E	C07. C	P07. C
B08. A	C08. C	P08. A
B09. E	C09. E	P09. C
B10. B	C10. A	P10. C
B11. C	C11. A	P11. E
B12. C	C12. C	P12. B
B13. D	C13. C	P13. D
B14. B	C14. C	P14. A
B15. B	C15. B	P15. E
B16. E	C16. E	P16. D
B17. D	C17. E	P17. D
B18. E	C18. C	P18. A
B19. C	C19. C	P19. B
B20. A	C20. D	P20. C

CHEMISTRY SOLUTIONS – UIL DISTRICT 2019

C01. (A) There is an empty spot in the 2*p* orbital but the outermost electron is in the higher-energy 3*s* orbital, so this atom is not in the ground state.

C02. (E) Melting point increases with higher ionic charge and smaller ionic radius.

C03. (D) The molar mass of the compound is 712.98 g/4.65 mol = 153.33 g/mol. From there it's just trial and error matching this number with the molar masses of the possible compounds.

C04. (E) The balanced equation is $2\ Au^{3+}(aq) + 6\ I^-(aq) \rightarrow 2\ Au(s) + 3\ I_2(s)$

C05. (D) $2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$
Determine the limiting reactant: (3.45 g)/(22.99 g/mol) = 0.150 mol Na
$n = PV/RT$ = (744/760)(2.5)/(0.08206)(298) = 0.100 moles Cl_2 – enough for 0.200 moles of NaCl.
Na is the limiting reactant, so 0.150 moles NaCl will form. 58.44 g/mol × 0.150 mol = 8.77 g NaCl

C06. (B) Since the gas is a mixture, both gases are at the same temperature. This means the molecules of both gases have the same average kinetic energy. KE = $\frac{1}{2}mv^2$, so the molecules with the higher mass must have a lower root mean square velocity.

C07. (C) The reaction is exothermic, therefore heat is given off by the reaction, and *q* is negative.
Work = $-P\Delta V = -\Delta nRT$. The change in the number of moles of gas (Δn) is (1) – (0) = 1, therefore $w = -RT$ and is also negative.

C08. (C) There are a few different ways of doing titration calculations, but this is the method I prefer:
At the equivalence point, moles H^+ = moles OH^-
moles $H^+ = M_{acid} \times V_{acid} \times$ number of H^+ in the acid formula ($H_2SO_4 = 2$)
moles $OH^- = M_{base} \times V_{base} \times$ number of OH^- in the base formula (NaOH = 1)
$M_{H2SO4} \times V_{H2SO4} \times 2 = M_{NaOH} \times V_{NaOH} \times 1$
$M_{H2SO4} \times 10.00\ mL \times 2 = 0.155\ M \times 33.88\ mL \times 1$
$M_{H2SO4} = 0.278\ M$

C09. (E) The liquid phase for this compound is more dense than the solid phase, so increasing the pressure on the solid phase will drive the compound into the liquid phase. This is only true for diagram E.

C10. (A) Moles of Cl^- = 0.100 L × 0.50 M × 3 = 0.150 mol. Moles of Ag^+ = 0.250 × 0.50 M = 0.125 mol. Chloride ions are in excess, so the chloride ions will precipitate out all the silver ions, and then you have AgCl(*s*) in a solution containing chloride ions. Initial [Ag^+] = 0 M and initial [Cl^-] = 0.150 – 0.125 = 0.025 moles/0.350 L = 0.071 M. Use this to construct a RICE table:

Reaction	AgCl (s) ⇌	Ag^+(aq)	+ Cl^-(aq)
Initial		0	0.071
Change		+ *x*	+ *x*
Equilibrium		*x*	0.071 + *x*

Assume $x << 0.071$ M, so $0.071 + x \approx 0.071$ M. $K_{sp} = 1.77 \times 10^{-10} = [x][0.071]$. $[x] = 2.5 \times 10^{-9}$ M.

C11. (A) To minimize repulsions, the three lone pairs will be in the equatorial positions around the central atom, leaving the two outer atoms bonded at the axial positions.

C12. (C) moles Na in the sample = (5.53 g)/(22.99 g/mol) = 0.241 mol
moles Cl in the sample = (8.53 g)/(35.45 g/mol) = 0.241 mol
If the remaining mass is oxygen, then moles O in the sample = (7.69 g)/(16.00 g/mol) = 0.481 mol
The molar ratio of Na:Cl:O in the compound is 1:1:2, so the compound is $NaClO_2$.

C13. (C) The reaction added 0.01 mol Cl^- to 0.005 mol of Pb^{2+} and should have formed a theoretical yield of 0.005 mol of $PbCl_2$, with a mass of 1.39 g. The student's actual yield is (impossibly) greater than the theoretical yield, so his product contains some contaminant. Since this was an aqueous reaction where the product had to be dried, most likely it is not fully dry. Mistakenly using NaBr instead of NaCl would yield 1.84 g of product, far more than the 1.53 actually measured.

C14. (C) $Au^+ + e^- \rightarrow Au(s)$ $E° = +1.83$, $Ag^+ + e^- \rightarrow Ag(s)$ $E° = +0.80$
Since the reduction of $Au^+(aq)$ to $Au(s)$ has a higher standard reduction potential than the reduction of $Ag^+(aq)$ to $Ag(s)$, $Au^+(aq)$ will be reduced at the cathode. (You could also determine this from the activity series if reduction potentials were not provided.) $Ag(s)$ will therefore be oxidized at the anode.

C15. (B) The balanced equation for the reaction is $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3\ H_2(g)$ If the volume is increased the pressure will drop, and Le Châtelier's principle says the equilibrium will shift to try to restore the pressure. Since there are two moles of gas on the reactant side and four moles of gas on the product side, the equilibrium will shift to the right to produce more moles of gas.

C16. (E) When $[A]_0$ is doubled and $[B]_0$ is held constant, the rate is approximately four times faster, indicating that the exponent on [A] is 2. When $[B]_0$ is doubled and $[A]_0$ is held constant, the rate doubles, indicating that the exponent on [B] is 1. The rate law is therefore rate = $k[A]^2[B]$

C17. (E) The easiest solution is to take the boiling point of water in kelvins and multiply it by 9/5 to account for the difference in degree size between °C and °F: 373.15 K × 9/5 = 671.67 °R.
Another approach is to take absolute zero on the Celsius scale (–273.15 °C) and convert °C to °F:
°F = –273.15 (9/5) + 32 = –459.67 °F
0 °R = –459.67 °F, so °R = °F + 459.67
212 °F + 459.67 = 671.67 °R

C18. (C) The chemical formula is $C_{13}H_{18}O_2$.

C19. (C) All the carbon atoms that have four single bonds around them are sp^3 hybridized.

C20. (D) AgI is highly insoluble in water ($K_{sp} = 8.52 \times 10^{-17}$), and is even less will dissolve in a solution that already contains iodide ions, so the $[I^-]$ contribution from AgI dissolving can be ignored and the problem becomes a simple dilution problem based on the moles of FeI_3.
Moles I^- = 0.630 L × 0.45 mol/L × 3 mol I^-/mol FeI_3 = 0.85 mol I^-. Diluted to 1 L, $[I^-]$ = 0.85 M.

PHYSICS SOLUTIONS – UIL DISTRICT 2019

P01. (A) page 23: "He [Kepler] also generated the next major and most radical shift yet – the search for laws, perennial truths that could be derived to describe and account for the motions of the celestial bodies. Kepler strived to develop celestial physics – he attempted to derive a physical theory that would provide an explanation for and describe the causes of the motion of the planets."

P02. (E) pages 60-61: "In 1946, the Ukraine-born American physicist George Gamow calculated how a primordial soup of particles might create the various chemical elements…. There was rising discontent with this hypothesis of an initial cosmic explosion…. What spurred the detractors of the Big Bang model was Gamow's failure to predict the formation of elements beyond hydrogen and helium."

P03. (D) page 100: "Zwicky studied the motions of the brightest eight galaxies in the Coma Cluster…. Zwicky found that the galaxies were all moving around much faster within the cluster than predicted if one took into account only the gravity of the visible stars…. He published these results in a 1933 paper that claims that the Coma Cluster, and the entire universe by extension, must have an invisible, unseen component, 'dunkle Materie,' or dark matter, whose gravity likely accounts for these vast speeds."

P04. (C) In the Sun, energy is produced by nuclear fusion in a small central region (the core). Then, radiation carries the energy produced in the core outward through the star. This radiative zone, a region of low opacity, extends about 70 percent of the way out toward the surface of the Sun.

P05. (B) Mass is equal to the density multiplied by the volume. First, then, we need to calculate the volume. This a cylinder, so the volume is $V = \pi r^2 L = \pi(1.314)^2(2.86) = 15.5[134]$ cm^3. The significant figures of the product are limited to three by the significant figures of the length of the cylinder. Then we can acquire the mass: $m = \rho V = (8.6\ g/cm^3)(15.5\ cm^3) = 13[3.415] \approx 130g$. Since everything is multiplied, the final answer is limited by the density, which was only given to two significant figures.

P06. (D) Since we have the time of the constant acceleration, and the initial velocity, we can use the following kinematic equation: $x = x_0 + v_0 t + \frac{1}{2}at^2 = 0 + (32)(8) + (0.5)(-2.78)(8)^2 = 167$m.

P07. (C) This is a little tricky, but since the inclined plane is frictionless, it isn't too hard. First, consider the free-body diagrams of the two blocks. For the hanging block, there are only two forces, gravity (m_1g) pointed down and the tension (T) pointed up. For the block on the incline, we have gravity (m_2g) pointed down, the normal force (F_N) pointed up and left, perpendicular to the plane; and the tension (T) point up and right, parallel to the plane.
Now we can write some equations. For the first block, which is accelerating downward, we have $\sum F = m_1 g - T = m_1 a$, or plugging in numbers, $98 - T = 10a$. For the second block, we tilt our coordinate axes to be parallel (x) and perpendicular (y) to the plane. The direction of acceleration of the second block is then entirely in the x-direction. Since our axes are tilted, we have to break m_2g into components: the x-component is $(m_2 g)_x = m_2 g sin\theta$, and the y-component is $(m_2 g)_y = m_2 g cos\theta$. Now we can sum our forces: $\sum F_x = T - m_2 g sin\theta = m_2 a$ and $\sum F_y = F_N - m_2 g cos\theta = 0$. There is no acceleration perpendicular to the plane, so $\sum F_y = 0$, which gives us the completely useless relation: $F_N = m_2 g cos\theta$. The useful equation comes from the forces in the x-direction: $T - m_2 g sin\theta = m_2 a$, or plugging in numbers, $T - 24.85 = 6a$. We have two equations and two unknowns: $98 - T = 10a$ and $T - 24.85 = 6a$. Combining these equations gives: $98 - 24.85 = 16a = 73.15$, or $a = 4.57$ m/s^2.

P08. (A) This is a two-part problem, commonly known as a ballistic pendulum. Let's begin with the collision and conservation of momentum: The momentum of the first acrobat before the collision is zero (he is stationary), but the momentum of the second acrobat is $p_{2i} = m_2 v_{2i} = (60)(12.5) = 750$ kgm/s. This gives the total initial momentum: $p_i = p_{1i} + p_{2i} = 0 + 750 = 750$ kgm/s. The total final momentum must be the same (conservation of momentum). However, after the collision, the two acrobats are moving together at the same velocity. Thus $p_f = m_1 v_f + m_2 v_f = (m_1 + m_2)v_f = (60 + 70)v_f = 130 v_f = 750$. This gives a final velocity of $v_f = 5.77$m/s.
Now we use conservation of energy to get the height to which the acrobats rise. Immediately after the collision, they have kinetic energy, but once they rise to their maximum height, they come to a stop and only have gravitational potential energy. As an equation, this is: $\frac{1}{2}mv^2 = mgh$. This simplifies to $h = \frac{v^2}{2g}$. The velocity to use is the velocity after the collision, so $v = 5.77$ m/s. Then the height to which the acrobats rise above their point of collision is: $h = \frac{(5.77)^2}{2(9.8)} = 1.70$m.

P09. (C) This is just a conservation of energy problem but including rotational kinetic energy. When the mass is first released, nothing is moving, so all the energy is in the form of the gravitational potential energy of the hanging mass. When the block reaches the floor, the energy has been converted into kinetic energy – both the linear kinetic energy of the mass and the rotational kinetic energy of the pulley. Putting this into equations yields: $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$. For a disk we are given that $I = \frac{1}{2}m_p r^2$ where m_p is the mass of the pulley. Note also that the rope does not slip on the pulley, which means $v = r\omega$. Putting it all together: $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = (20)(9.8)(4.40) = (0.5)(20)v^2 + (0.5)\,\frac{1}{2}m_p r^2\omega^2$. Observe that $r^2\omega^2 = v^2$. So, we have: $862.4 = 10v^2 + (0.25)(9.00)v^2 = 12.25v^2$. This gives $v = \sqrt{\frac{862.4}{12.25}} = 8.39$ m/s. From this we can determine the angular speed of the pulley: $\omega = \frac{v}{r} = \frac{8.39}{0.65} = 12.9$ rad/s.

P10. (C) For an open-open pipe, the frequency is given by $f = \frac{nv}{2L}$, where v is the speed of sound. At room temperature (20°C), the speed of sound is 343m/s. The problem references the seventh resonance, so n = 7. Plugging all this into the equation: $f = 512 = \frac{(7)(343)}{2L}$. Solving for length yields: $L = \frac{2401}{1024} = 2.34$m.

P11. (E) We begin this problem by using Bernoulli's equation. The points of interest are at the end points of the fluid – at the top of the reservoir, and where the pipe empties into the pond. We choose these because those points are where the base pressure is equal to atmospheric pressure. So, applying Bernoulli's equation: $P_A + \rho g h_A + \frac{1}{2}\rho v_A^2 = P_B + \rho g h_B + \frac{1}{2}\rho v_B^2$. Let point A be at the top of the reservoir, and point B be at the end of the pipe. Note that the fluid at point A isn't really moving, and that the height at point B is zero. Plugging in, we get: $P_{atm} + \rho g h_A + \frac{1}{2}\rho(0)_A^2 = P_{atm} + \rho g(0) + \frac{1}{2}\rho v_B^2$. Cancelling the atmospheric pressure and plugging in the numbers: $(1100)(9.8)(4.60) = (0.5)(1100)v_B^2$. This gives us a value for the fluid speed at point B: $v_B = 9.50$ m/s.

Now we use the continuity equation to acquire the fluid speed at the narrow portion of the pipe. $A_C v_C = A_B v_B$. Choosing point C to be in the narrow portion of the pipe and noting that the pipes are round (and thus, have circular cross-sections), we get: $\pi r_C^2 v_C = \pi r_B^2 v_B$. Cancelling the pi and noting that we were given diameters for the two regions of the pipe, we get: $(0.10)^2 v_C = (0.14)^2(9.50)$. Thus, $v_C = 18.6$ m/s.

P12. (B) This is a standard series-parallel resistor problem. First recall that resistors in parallel have the same voltage across them. This tells us that $V_{60} = V_{75} = 3.50$V. Now we can get the currents through these two resistors: $I_{75} = \frac{3.50}{75} = 0.0467$A, and $I_{60} = \frac{3.50}{60} = 0.0583$A. Adding these currents gives the total current flowing through the middle branch of the circuit, which happens to be the current in the 40Ω resistor: $I_{40} = I_{75} + I_{60} = 0.105$A. This allows us to get the voltage across the 40Ω resistor: $V_{40} = (0.105)(40) = 4.20$V. Voltages in series add, so we can combine the voltage across the 40Ω resistor and the (60Ω||75Ω) parallel group. This gives the total voltage across the entire middle branch: $V_M = 4.20 + 3.50 = 7.70$V. Noting that the middle branch is in parallel with the other resistor (90Ω) and in parallel with the battery, then they must all have the same voltage, thus the voltage across the battery is $V = V_M = 7.70$V.

P13. (D) Let's consider each charge separately. The equation for the magnitude of the electric field at a distance *r* from a charge *Q* is given by $|E| = \frac{kQ}{r^2}$. For the first charge: $|E|_1 = \frac{(8.99\times10^9)(610\times10^{-9})}{(4.50\times10^{-2})^2} = 2.71\times10^6$ N/C. For the second charge: $|E|_2 = \frac{(8.99\times10^9)(470\times10^{-9})}{(3.00\times10^{-2})^2} = 4.69\times10^6$ N/C. Here we have dropped the negative sign since we are only considering the magnitude. Now, electric fields are vectors, so we must consider the directions of these two fields before combining them. The positive charge on the y-axis will produce an electric field at the origin that is directed downward (away from the charge), while the negative charge on the x-axis will produce an electric field at the origin that is directed to the right (towards the charge). These two field vectors are perpendicular – thus, we can combine these vectors by using the Pythagorean Theorem. Thus, the magnitude of the electric field at the origin is:
$|E| = \sqrt{|E|_1^2 + |E|_2^2} = \sqrt{(2.71\times10^6)^2 + (4.69\times10^6)^2} = 5.42\times10^6$ N/C.

P14. (A) The path traced by a charge particle in a magnetic field is a circle with a radius given by $r = \frac{mv}{qB}$. The atoms are singly ionized, so $q = 1.602 \times 10^{-19}$ C, and the location X is the circle's diameter, which gives $r = 31.0cm = 0.31$m. Plugging it all in: $0.31 = \frac{m(7500)}{(1.602 \times 10^{-19})(6000 \times 10^{-6})} = 7.80 \times 10^{24}m$. This gives a mass of $m = 3.97 \times 10^{-26}$ kg, or, converting to atomic mass units, $m = 23.9$amu.

P15. (E) From the peak electric field, we can acquire the intensity of the laser: $I = \frac{1}{2}c\epsilon_0\left|E_{peak}\right|^2$. Since we know all these values, $I = (0.5)(3.00 \times 10^8)(8.854 \times 10^{-12})(500)^2 = 332$ W/m^2. Intensity is also the power per unit area, or $I = \frac{P}{A}$. For a circular beam, $A = \pi r^2$. Thus, $I = 332 = \frac{P}{\pi r^2} = \frac{P}{\pi(3.00 \times 10^{-3})^2}$. This gives the average power of the laser: $P = (332)\pi(9.00 \times 10^{-6}) = 0.00940$W, or $P = 9.40$mW.

P16. (D) A convex mirror will have a negative focal length, so $f = \frac{R}{2} \rightarrow f = -\frac{28}{2} = -14.0$cm. Now we can work in centimeters to find the image location: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{1}{12.0} + \frac{1}{q} = \frac{1}{-14.0}$, which gives $q = -6.46$cm. To get the magnification, we use $M = -\frac{q}{p} = -\frac{-6.46}{12} = +0.54$.

P17. (D) The selection rule limits which transitions can happen. For example, we can go from the 3s to the 2p state, but we are not allowed to go from the 3s to the 2s. There are only six downward transitions allowed by this selection rule. Listing them, and the energy differences between these states we have:
3d → 3p (ΔE = 0.16eV), 3d → 2p (ΔE = 1.04eV), 3p → 3s (ΔE = 0.21eV), 3p → 2s (ΔE = 1.44eV), 3p → 1s (ΔE = 2.79eV), and 3s → 2p (ΔE = 0.67eV). Now we convert these energy differences into photon wavelengths using the formula $\lambda = \frac{1240\ eVnm}{\Delta E}$. Thus, the wavelengths that could be emitted by this kind of atom would be: 7750nm, 5910nm, 1850nm, 1190nm, 861nm, and 444nm. The only one of these that is a choice is $\lambda = 1190$nm (which is the 3d → 2p transition).

P18. (A) To answer this, we must go down our list of conservation laws. First, there is conservation of charge: there is a net zero charge on the left side, so there must be the same on the right side – meaning the unknown particle must be neutral (eliminating choices B and E). Second, there is baryon number: there is one baryon on the left (the proton) and one baryon on the right (the neutron). This is already balanced, so the unknown particle must not be a baryon (eliminating choice D).

The last one is tricky. This is a strong force interaction, so quark flavor numbers like strangeness and charm, must also be conserved. None of the given particles have a non-zero quark flavor number; thus, the unknown particle must have zero for all of its quark flavor numbers. The kaon (choice C) has a strangeness of -1, so it cannot be the correct choice. This leaves the neutral rho-meson (A) as the only choice that does not violate any conservation laws in a strong-force particle interaction.

P19. (B) The equation that relates the period of a pendulum to the length of the pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. By graphing T^2 versus L, the data produces a linear plot, from the equation: $T^2 = 4\pi^2\frac{L}{g}$. So, the equation of the line on the graph is of the form $y = \frac{4\pi^2}{g}x$. Clearly, the slope of the line is $(slope) = \frac{4\pi^2}{g}$. From the graph itself, we can get a slope of approximately $(slope) = \frac{6.0-3.0}{2.0-1.0} = 3.0$ s^2/m. Then, solving for the gravitational acceleration: $g = \frac{4\pi^2}{slope} = \frac{4\pi^2}{3} = 13.1$ m/s^2.

P20. (C) Although it is interesting that this graph is linear, and the slope of the graph (as usual) does mean something, the slope is not what we need to answer this question. Note that the equation for photoelectron kinetic energy is $KE = hf - \phi$. The workfunction, ϕ, is not related to the slope of the graph, but instead to the intercept. The x-intercept, when $KE = 0$, is when $\phi = hf_0$. From the graph itself, the cutoff frequency (x-intercept), f_0, is about 5.0×10^{14} Hz. This means the workfunction is $\phi = hf_0 = (6.626 \times 10^{-34})(5.0 \times 10^{14}) = 3.3 \times 10^{-19}$ J. Converting to eV gives a workfunction of $\phi = \frac{3.3 \times 10^{-19}}{1.602 \times 10^{-19}} = 2.1$eV.

UIL Science Contest Answer Sheet

Conference _____ **Grade Level** _____ **Contestant #** _____

Biology	Chemistry	Physics
B01 _____	C01 _____	P01 _____
B02 _____	C02 _____	P02 _____
B03 _____	C03 _____	P03 _____
B04 _____	C04 _____	P04 _____
B05 _____	C05 _____	P05 _____
B06 _____	C06 _____	P06 _____
B07 _____	C07 _____	P07 _____
B08 _____	C08 _____	P08 _____
B09 _____	C09 _____	P09 _____
B10 _____	C10 _____	P10 _____
B11 _____	C11 _____	P11 _____
B12 _____	C12 _____	P12 _____
B13 _____	C13 _____	P13 _____
B14 _____	C14 _____	P14 _____
B15 _____	C15 _____	P15 _____
B16 _____	C16 _____	P16 _____
B17 _____	C17 _____	P17 _____
B18 _____	C18 _____	P18 _____
B19 _____	C19 _____	P19 _____
B20 _____	C20 _____	P20 _____
B Score ☐	**C Score** ☐	**P Score** ☐

Grader Initials _____ _____ _____ **OVERALL SCORE** ☐