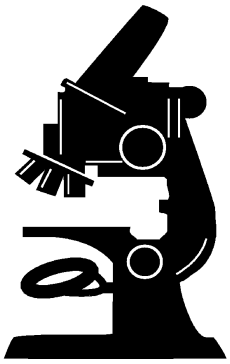
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Invitational A • 2018



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. An organism that inherits two of the same alleles for a single trait is
A) homozygous.
B) haploid.
C) heterozygous.
D) hemizygous.
E) polyploid.

B02. Analyze the following answer choices. Which one is not a catabolic pathway?
A) fermentation
B) anaerobic respiration
C) aerobic respiration
D) protein synthesis
E) glycolysis

B03. In a phospholipid, the fatty acid tails are _____ and the "head," which is made of phosphate and choline, is _____.
A) hydrophobic; hydrophobic
B) hydrophobic; hydrophilic
C) hydrophilic; hydrophilic
D) hydrophilic; hydrophobic

B04. All of the following are vascular plants except
A) flowering plants.
B) ferns.
C) eudicots.
D) gymnosperms.
E) mosses.

B05. Replicate the following DNA template strand:

3'-CAGGTTCAAG-5'

A) 5'-CAGGTTCAAG-3'
B) 5'-GUCCAAGUUC-3'
C) 3'-GTCCAAGTTC-5'
D) 5'-CAGGUUCAAG-3'
E) 5'-GTCCAAGTTC-3'

B06. The _____ structure of a protein encompasses ionic bonds, hydrophobic interactions, disulfide bridges, and hydrogen bonds to generate a three-dimensional shape.
A) primary
B) secondary
C) tertiary
D) quaternary

B07. Which tissue is excitable, conductive, and under voluntary control?
A) skin
B) skeletal muscle
C) autonomic neurons
D) nervous tissue
E) cardiac muscle

B08. *Homo sapiens* belongs to Supergroup
A) Opisthokonta.
B) SAR.
C) Excavata.
D) Archaeplastida.
E) Amoebozoa.

B09. A high school teacher assigns his students a project in which he gives them the characteristics for an unknown cell and asks the students to formulate hypotheses. One group of students is given a cell with the following characteristics:

80S ribosomes, no chlorophyll, cell wall made of chitin, saprophytic, aerobic metabolism

Which of the following hypotheses would most likely be supported upon further investigation?
A) The unknown cell type is a prokaryote.
B) The unknown cell type is a eukaryote belonging to Kingdom Fungi.
C) The unknown cell type is a eukaryote belonging to Kingdom Plantae.
D) The unknown cell type is a green algae.
E) The unknown cell type is a freshwater protozoan called *Euglena*.

B10. In the nitrogen cycle, _____ is the process of oxidizing ammonium (NH_4^+) to nitrite (NO_2^-) and nitrate (NO_3^-).
A) ammonification
B) denitrification
C) assimilation
D) nitrification
E) nitrogen fixation

B11. The esophagus is a muscular tube that belongs to which body organ system?
A) Lymphatic
B) Respiratory
C) Digestive
D) Nervous
E) Endocrine

B12. The MMR combination vaccine is designed to protect against all of the following viral infections, except
A) measles.
B) roseola.
C) mumps.
D) rubella.
E) German measles.

B13. All of the following cell division processes generate haploid cells in humans, except
A) mitosis.
B) meiosis.
C) oogenesis.
D) gametogenesis.

B14. Which of these statements describes the process of translation?
A) The flow of genetic information from DNA to RNA.
B) The copying of DNA to transmit the genetic information to daughter cells during cell division.
C) The generation of an amino acid sequence from a specific order of codons on messenger RNA.
D) The expression of a gene on DNA into tRNA or rRNA.
E) Vertical gene transfer during mitosis.

B15. A Mendelian dihybrid cross in which both parents are heterozygous for both traits would yield a phenotypic ratio of _____.
A) 1:2:1
B) 3:1
C) 1:1
D) 9:3:3:1
E) none of the above

B16. Inserting or deleting a base from a DNA coding region would result in which type of mutation?
A) nonsense
B) missense
C) frameshift
D) silent
E) substitution

B17. In an experiment, 1000 fruit flies were divided into two populations (Pop. A and Pop. B), kept separate from each other, and fed different diets. After several generations, the fruit fly populations were allowed to co-mingle. The researchers observed that flies from each population did not readily mate with one another. Pop. A preferred to mate in the morning and Pop. B mated only in afternoon. Which term would best describe the reproductive isolation mechanism?
A) Post-zygotic separation
B) Gametic isolation
C) Behavioral isolation
D) Mechanical isolation
E) Temporal isolation

B18. Anything associated with a microbial pathogen that enhances its disease-causing ability is called a/an
A) antigen.
B) antibody.
C) etiologic agent.
D) virulence factor.
E) growth factor.

B19. All of the following answer choices are examples of symbiosis. Which is the best example of mutualism?

A) Nitrogen-fixing bacteria residing within root nodules of leguminous plants.
B) A domesticated dog having fleas.
C) Tapeworms inside a mammal's intestines, consuming nutrients and leading to malnutrition and weight loss.
D) Fungi growing on the side of a dead tree by secreting enzymes and absorbing the digested products.
E) A viral infection in a human cell.

B20. In the following biochemical reaction catalyzed by an enzyme called lactate dehydrogenase, which statement is true?

$$2\ \text{Pyruvate} + 2\text{NADH} \rightarrow 2\ \text{Lactate} + 2\text{NAD}^+$$

A) Pyruvate is the substrate and binds to the active site of lactate dehydrogenase.
B) This process is lactate fermentation.
C) Lactate is more reduced than pyruvate.
D) The NAD^+ is the oxidized form of the coenzyme.
E) All of the above statements are true.

C01. How many atoms are in one mole of C_6H_{14}?

A) 6.022×10^{23}
B) 1.204×10^{24}
C) 6.022×10^{24}
D) 1.204×10^{25}
E) 6.022×10^{25}

C02. What is the molar mass of gaseous dinitrogen tetroxide?

A) 30.01 g/mol
B) 44.02 g/mol
C) 46.01 g/mol
D) 88.04 g/mol
E) 92.02 g/mol

C03. What is the sum of the coefficients when this chemical equation is balanced?

$$Fe + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + H_2$$

A) 12
B) 9
C) 8
D) 7
E) 4

C04. What is the pH of a 0.0075 M $Ba(OH)_2$ solution?

A) 12.18
B) 11.88
C) 7.5
D) 2.12
E) 1.82

C05. What is the mass percent iron in Fe_2O_3?

A) 30.06%
B) 34.97%
C) 55.85%
D) 69.94%
E) 111.70%

C06. Which of these lines in the hydrogen emission spectrum is visible to the human eye?

A) 122 nm
B) 656 nm
C) 1094 nm
D) 1282 nm
E) 1875 nm

C07. How do the intermolecular forces in solid wax compare to the intermolecular forces in molten wax?

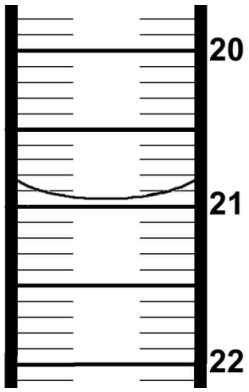
A) Solid wax has hydrogen bonding but molten wax only has dipole-dipole forces.
B) Solid wax has hydrogen bonding but molten wax only has dispersion forces.
C) Solid wax has dipole-dipole attractions, but molten wax only has dispersion forces.
D) Solid wax has dispersion forces and molten wax has no intermolecular forces.
E) The intermolecular forces in solid wax and in molten wax are the same.

C08. What is the net ionic equation for the reaction of lead(II) nitrate with potassium iodide?

A) $2\ PbNO_3(aq) + KI(aq) \rightarrow 2\ PbI(s) + KNO_3(aq)$
B) $Pb_2NO_3(aq) + KI(aq) \rightarrow Pb_2I(s) + KNO_3(aq)$
C) $Pb^{2+}(aq) + 2\ NO_3^-(aq) + 2\ K^+(aq) + 2\ I^-(aq) \rightarrow PbI_2(s) + 2\ KNO_3(aq)$
D) $Pb^{2+}(aq) + 2\ I^-(aq) \rightarrow PbI_2(s)$
E) $K^+(aq) + NO_3^-(aq) \rightarrow KNO_3(s)$

C09. What is the correct volume reading for the liquid in this burette?

A) 20.84 mL
B) 20.96 mL
C) 20.90 mL
D) 21.05 mL
E) 21.16 mL



C10. A piece of silvery metal measuring 2.0 cm × 2.0 cm × 5.0 cm has a mass of 178.60 g. Which of these metals is it most likely to be?

A) Aluminum
B) Iron
C) Cobalt
D) Nickel
E) Copper

C11. If you sprinkled table salt into a saturated solution of lead(II) chloride, what would happen to the concentrations of the dissolved lead and chloride ions?

A) The lead ion concentration would decrease and the chloride concentration would increase.
B) The chloride concentration would increase but the lead ion concentration would stay the same.
C) The table salt would not dissolve, so the lead and chloride concentrations would remain unchanged.
D) The lead ions would precipitate out the added chloride ions, so both the lead and chloride ion concentrations would decrease from their initial levels.
E) The chloride concentration would increase until it was equal to the lead concentration, then no more table salt would dissolve.

C12. If a piece of dry ice (solid CO_2) weighing 2.85 grams is allowed to sublimate in a tied-off balloon at 25°C and 1 atm pressure, what will the final volume of the balloon be?

A) 2.85 mL
B) 0.44 L
C) 1.45 L
D) 1.58 L
E) 22.4 L

C13. What is the name of the compound Cu_2O?

A) copper oxide
B) copper(I) oxide
C) copper(II) oxide
D) cupric oxide
E) dicopper monoxide

C14. Three ice cubes with a total mass of 48.22 g are placed in a glass of tea. How much heat will be absorbed from the tea in order to completely melt the ice?

A) 16.1 kJ
B) 8.01 kJ
C) 2.25 kJ
D) 5.37 kJ
E) 10.1 kJ

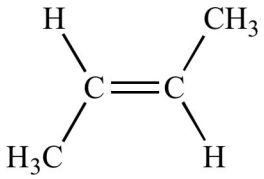
C15. Arrange the following atoms and ions in order of increasing radius: O^{2-} Mg^{2+} Ne Na^{+} F^{-}

A) $Mg^{2+} < Na^{+} < Ne < F^{-} < O^{2-}$
B) $O^{2-} < F^{-} < Ne < Na^{+} < Mg^{2+}$
C) $Mg^{2+} < Na^{+} < O^{2-} < F^{-} < Ne$
D) $Ne < Mg^{2+} < Na^{+} < O^{2-} < F^{-}$
E) These species are isoelectronic and therefore have the same radius.

C16. If 235.0 mL of water is added to 175 mL of 0.85 M aluminum chlorate, what will the final concentration of chlorate ions be in solution?

A) 0.63 M
B) 0.362 M
C) 1.09 M
D) 0.85 M
E) 0.726 M

C17. How many σ bonds and how many π bonds are in one molecule of trans-2-butene?



A) 4 σ bonds and 2 π bonds
B) 5 σ bonds and 1 π bond
C) 5 σ bonds and 0 π bonds
D) 10 σ bonds and 2 π bonds
E) 11 σ bonds and 1 π bond

C18. When hydrocarbons are burned in the presence of limited oxygen, carbon monoxide is formed. Calculate the heat of reaction for the incomplete combustion of one mole of methane. The balanced incomplete combustion reaction is

$$2\ CH_4(g) + 3\ O_2(g) \rightarrow 2\ CO(g) + 4\ H_2O(l)$$

A) –1214 kJ
B) –607 kJ
C) –1456 kJ
D) +1456 kJ
E) –324 kJ

C19. What is the difference between atomic mass and mass number?

A) There is no difference, they both mean the same thing.
B) Atomic mass is the mass of a single atom and mass number is the mass of one mole of atoms.
C) Atomic mass is the mass of the atom and mass number is the number of protons in the nucleus.
D) Atomic mass is a weighted average of all naturally-occurring isotopes of an element, and mass number is the number of protons and neutrons in the nucleus of one isotope of that element.
E) Atomic mass can be expressed in grams or daltons, but mass number is always in grams.

C20. Hydrogen and nitrogen react at high temperatures and pressures to form ammonia gas by the reaction

$$3\ H_2(g) + N_2(g) \rightleftarrows 2\ NH_3(g)$$

K_c for this reaction at 300°C = 9.6.

If 0.10 moles of H_2, 0.035 moles of N_2, and 0.025 moles of NH_3 are added to a 1.0 L container and the temperature is increased to 300°C, what will happen?

A) Q = 7.1, so H_2 and N_2 will react to produce more NH_3.
B) Q = 7.1, so NH_3 will decompose to form more H_2 and N_2.
C) Q = 18, so H_2 and N_2 will react to produce more NH_3.
D) Q = 18, so NH_3 will decompose to form more H_2 and N_2.
E) The forward and reverse reaction rates will increase proportionately, so the concentrations will remain at their original levels.

P01. According to Tyson, what happened when the temperature of the early universe fell below 3,000 Kelvin?
A) gravity wriggled loose from the other unified forces of nature.
B) the universe had grown to a few light-years across.
C) all the free electrons combined with nuclei.
D) the strong and electroweak forces parted company.
E) quarks all grabbed partners creating a new family of particles called hadrons.

P02. According to Tyson, an unknown spectral signature discovered by astrophysicists was deemed a new element called "nebulium". However, nebulium was just the signature of an ordinary element doing extraordinary things. Which element was it?
A) Hydrogen
B) Helium
C) Nitrogen
D) Carbon
E) Oxygen

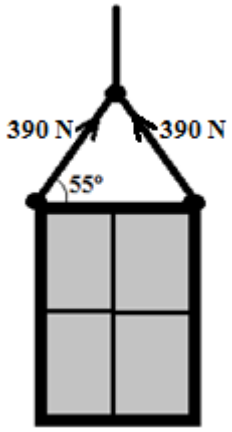
P03. According to Tyson, dwarf galaxies outnumber large galaxies by more than …
A) two to one.
B) ten to one.
C) fifty to one.
D) a hundred to one.
E) a thousand to one.

P04. What is the temperature of the outermost part of the Sun's atmosphere, the corona?
A) 16 million Kelvin
B) 1-2 million Kelvin
C) 100,000 Kelvin
D) 6000 Kelvin
E) 4500 Kelvin

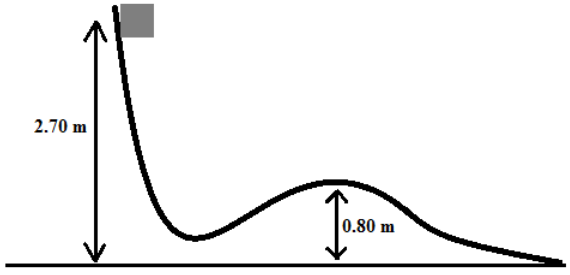
P05. A droplet of oil with a volume of 0.500ml lands on the still water surface of a swimming pool. The oil spreads on the surface into a perfect circle with a radius of 2.50 m. What is the thickness of the oil film on the surface of the water?
A) 25.5 nm
B) 64.7 nm
C) 80.0 nm
D) 251 nm
E) 417 nm

P06. A jet powered sled provides a steady horizontal acceleration of 12.5 m/s^2. If the sled starts from rest and accelerates for 5.00 seconds, how far has the sled travelled in that time?
A) 31.3 m
B) 62.5 m
C) 125 m
D) 156 m
E) 313 m

P07. A rectangular window is being held by two ropes tied at its corners as shown. Those two ropes are tied to a main cable located directly above the center of the window. What is the mass of the window if the tension in both the corner ropes is 390.0 N?
A) 22.8 kg
B) 32.6 kg
C) 45.7 kg
D) 65.2 kg
E) 79.6 kg



P08. A block starts from rest at the top of a slide and is located 2.70 m above the ground (as shown). A bump in the middle of the slide rises 0.80 m above the ground. Ignoring friction, what is the speed of the block at the top of the bump?



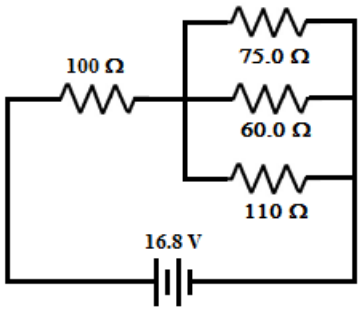
A) 3.96 m/s
B) 4.32 m/s
C) 6.10 m/s
D) 7.27 m/s
E) 8.28 m/s

P09. A rigid steel rod with a mass of 1.50 kg and a length of 1.20 m is attached to a pivot at its left end and held horizontally. A downward force of 10.0 N is applied at a point 20.0 cm from the rod's right end. Given that the moment of inertia of a rod rotated about one end is $I = \frac{1}{3}mL^2$, calculate the angular acceleration of the rod at the instant it is released.
A) 34.3 rad/s^2
B) 26.1 rad/s^2
C) 15.0 rad/s^2
D) 12.3 rad/s^2
E) 1.64 rad/s^2

P10. A 100.0 g mass is hung from a spring with an unknown spring constant. The mass is pulled and released, after which is oscillates with a period of 1.12 seconds. What would the period of oscillation be if the mass were changed to 250.0 g?
A) 0.282 seconds
B) 0.708 seconds
C) 1.11 seconds
D) 1.77 seconds
E) 2.80 seconds

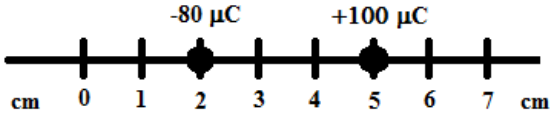
P11. Each cycle, an engine takes in 1500 J of heat energy and exhausts 900 J of heat energy. What is the efficiency of the engine?
A) 25 %
B) 33 %
C) 40 %
D) 60 %
E) 67 %

P12. Given the following circuit, determine the current flowing in the 75.0Ω resistor.



A) 45.6 mA
B) 59.0 mA
C) 134 mA
D) 178 mA
E) 224 mA

P13. Two charges (-80 μC and +100 μC) are arranged on the x-axis as shown. What is the net force on the +100 μC charge?



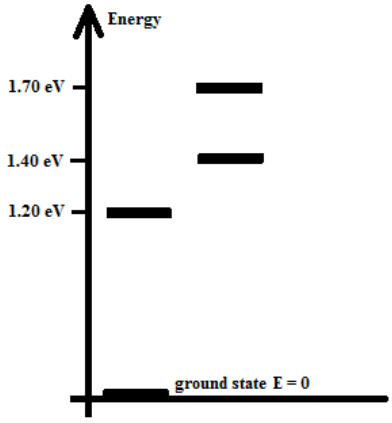
A) 2.9×10^4 N left
B) 2.9×10^4 N right
C) 7.2×10^4 N left
D) 8.0×10^4 N left
E) 8.0×10^4 N right

P14. A beam of singly-ionized lithium atoms (mass = 6.00 u) is moving with a velocity of 8.50×10^5 m/s. The beam enters a region with a magnetic field that is perpendicular to the velocity of the beam. The strength of the magnetic field is 0.0500 T. What is the radius of curvature of the circle traced out by the beam in the magnetic field?
A) 0.177 m
B) 0.639 m
C) 1.06 m
D) 1.70 m
E) 2.82 m

P15. An un-polarized laser beam with an intensity of 300.0 mW/m^2 passes through a pair of linear polarizers and emerges with an intensity of 90.0 mW/m^2. What is the angle between the polarization axes of the two polarizers?
A) 73 degrees
B) 69 degrees
C) 57 degrees
D) 53 degrees
E) 39 degrees

P16. You are trying to use a diverging lens to examine a small leaf. The leaf is 5.00mm long and the focal length of the lens is -20.0 cm. If you hold the lens at a distance of 4.00 cm from the leaf, what is the size of the image of the leaf? (Note: diverging lenses don't make very good magnifiers!)
A) 6.25 mm
B) 4.16 mm
C) 3.33 mm
D) 1.25 mm
E) 0.833 mm

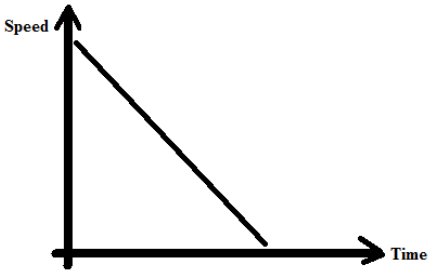
P17. You have the following energy level diagram for a certain atomic species. Ignoring selection rules, which of these wavelengths would you NOT expect to see emitted from an excited collection of these atoms?



A) 6200 nm
B) 2480 nm
C) 1030 nm
D) 954 nm
E) 729 nm

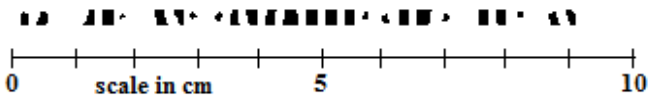
P18. A radioactive isotope of Thorium (Thorium-233) follows the following decay chain: alpha, alpha, beta-, gamma, beta-, alpha. What is the final daughter product?
A) Lead-219
B) Lead-221
C) Astatine-220
D) Radon-219
E) Radon-221

P19. Given the following graph of speed versus time for a toy car, describe qualitatively what is happening with the position, speed, and acceleration of the car.



A) position is increasing; speed is decreasing; acceleration is negative.
B) position is decreasing; speed is decreasing; acceleration is negative.
C) position is increasing; speed is increasing; acceleration is zero.
D) position is increasing; speed is decreasing; acceleration is positive.
E) position is decreasing; speed is decreasing; acceleration is positive.

P20. A laser with a wavelength of 632.8 nm is directed onto a double slit. The resulting interference pattern is projected onto a wall that is 1.50m from the double slit. Shown below is the interference pattern observed on the wall. From this, determine the approximate separation of the two slits.



A) 0.44 mm
B) 0.31 mm
C) 0.20 mm
D) 0.13 mm
E) 0.048 mm

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)

<u>water data</u>

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*

<u>constants</u>

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

Densities of Some Metals

<u>Element</u>	<u>Symbol</u>	<u>Density g/cm^3</u>
Sodium	Na	0.97
Magnesium	Mg	1.74
Aluminum	Al	2.70
Barium	Ba	3.62
Titanium	Ti	4.51
Tin	Sn	7.26
Iron	Fe	7.87
Cobalt	Co	8.86
Nickel	Ni	8.90
Copper	Cu	8.96
Silver	Ag	10.5
Lead	Pb	11.3
Mercury	Hg	13.5
Gold	Au	19.3
Platinum	Pt	21.5

Enthalpy of Reaction

<u>Reaction</u>	<u>ΔH_{rxn}</u>
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	–890 kJ
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$	–566 kJ

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	u	$1.66 \times 10^{-27}\ kg$
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 in air (at 20ºC)	v	343 m/s
Avogadro's Number	N_A	$6.022 \times 10^{23}\ atoms/mol$
Electron Volts	eV	$1.602 \times 10^{-19}\ J/eV$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2018 Invitational A

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

CHEMISTRY SOLUTIONS – UIL INVITATIONAL A 2018

C01. (D) There are 20 atoms in each C_6H_{14} molecule, so one mole of hexane will contain 20 atoms/molecule × 6.022×10^{23} molecules/mole = 1.204×10^{25} atoms.

C02. (E) The molar mass of N_2O_4 = (2 × 14.01) + (4 × 16.00) = 92.02 g/mol

C03. (B) 2 Fe + 3 H_2SO_4 → 1 $Fe_2(SO_4)_3$ + 3 H_2 2 + 3 + 1 + 3 = 9

C04. (A) $[OH^-] = 0.0075 \times 2 = 0.0150$. pOH = –log(0.0150) = 1.82.
pH = 14 – pOH = 14 – 1.82 = 12.18

C05. (D) Molar mass = (2 × 55.85) + (3 × 16.00) = 159.70 g/mol
Mass of iron / molar mass = (2 × 55.85)/159.70 = 0.6994
Mass percent iron = 69.94%

C06. (B) The visible region of the spectrum ranges roughly from 400 nm to 750 nm.

C07. (E) The intermolecular forces between wax molecules in both cases are dispersion forces, but molten wax has a higher temperature than solid wax, and the increased kinetic energy of the molecules in molten wax allows them to partially overcome the IMF's between wax molecules.

C08. (D) All the other ions in this reaction are spectator ions (they appear both as reactants and as products in the equation), and are therefore not included in a net ionic equation.

C09. (B) Volume is always read from the bottom of the meniscus.

C10. (D) Density = mass/volume = 1.78.60 g / (2.0 × 2.0 × 5.0) = 8.93 g/cm^3
This density value is halfway in between those of nickel and copper, but the question says it is "a silvery metal" and copper is brown, so the metal is most likely nickel.

C11. (A) As NaCl dissolves, $[Cl^-]$ increases, precipitating out more $PbCl_2$ (Le Châtelier's principle), which drives $[Pb^{2+}]$ lower.

C12. (D) The molar mass of CO_2 = 12.01 + (2 × 16.00) = 44.01 g/mol
Moles of CO_2 = 2.85 g / 44.01 g/mol = 0.06476 mol
T = 25°C + 273 = 298 K
$PV = nRT$, so $V = nRT/P$ = (0.06476 × 0.08206 × 298)/ 1 = 1.58 L

C13. (B) Because copper can form more than one type of ion in ionic compounds, the oxidation state must be specified in the name, using a Roman numeral. The O^{2-} ion is the oxide ion.

C14. (A) ΔH_{fus} for H_2O =334 J/g 334 J/g × 48.22 g = 16,105 J = 16.1 kJ

C15. (A) Generally speaking, as the positive charge on an ion increases, the ion becomes smaller. As the negative charge on an ion increases, the ion becomes larger. Since these species are all isoelectronic, their relative sizes can be determined from their charges.

C16. (C) The compound is $Al(ClO_3)_3$. Moles of ClO_3^- = 0.85 m/L × 0.175 L × 3 = 0.446 mol
The final volume is 0.175 L + 0.235 L = 0.410 L
The final concentration of ClO_3^- is 0.446 mol/0.410 L = 1.09 M.
We can keep three significant digits in the answer even though the $Al(ClO_3)_3$ concentration is given to only two, because to calculate the ClO_3^- concentration the initial $Al(ClO_3)_3$ concentration is multiplied by an exact number (3). 0.85 × 3 is the same as adding 0.85 + 0.85 + 0.85 = 2.55, and in this operation we gain one significant digit.

C17. (E) All single bonds and the first bond in a double or triple bond are σ bonds. The additional bonds in a double to triple bond are π bonds. Don't forget that there are three more single bonds in each CH_3 group.

C18. (B) Given these combustion reactions:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\quad \Delta H°_{rxn} = -890$ kJ
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\quad \Delta H°_{rxn} = -566$ kJ

To derive the chemical equation we want from the two equations provided, we double the first reaction, reverse the second reaction, and add them. This means we must also double the $\Delta H°_{rxn}$ for the first reaction, reverse the sign on the $\Delta H°_{rxn}$ for the second reaction, and then add them:

$2\ CH_4(g) + 4\ O_2(g) \rightarrow 2\ CO_2(g) + 4\ H_2O(l)$ $\quad \Delta H°_{rxn} = -1780$ kJ
$2\ CO_2(g) \rightarrow 2\ CO(g) + O_2(g)$ $\quad \Delta H°_{rxn} = +566$ kJ
$2\ CH_4(g) + 3O_2(g) \rightarrow 2\ CO(g) + 4\ H_2O(l)$ $\quad \Delta H°_{rxn} = -1214$ kJ

This is the heat of reaction for the incomplete combustion of 2 moles of methane, and the question asks for the heat of reaction for one mole of methane, so divide the result by 2:
$\Delta H°_{rxn} = -607$ kJ

C19. (D) Atomic mass is a weighted average of all naturally-occurring isotopes of an element, and mass number is the number of protons and neutrons in the nucleus of one isotope of that element.

C20. (D)

$$Q = \frac{[NH_3]^2}{[H_2]^3[N_2]} = \frac{[0.025]^2}{[0.10]^3[0.035]} = 18$$

The reaction quotient *Q* is greater than *K*, which means the reaction is not at equilibrium because there is too much product in the mixture relative to the amount of reactants present. Therefore Le Châtelier's principle dictates that the reverse reaction will occur to decrease the excess product and form additional reactant.

SELECTED PHYSICS SOLUTIONS – UIL INVITATIONAL A 2018

P01. (C) page 28 "…when the temperature of the universe falls below 3,000 degrees Kelvin … and all the free electrons combine with nuclei."

P02. (E) page 38 "Nebulium was simply the signature of ordinary oxygen doing extraordinary things."

P03. (B) page 64 "In any reliably surveyed volume of space, dwarf galaxies outnumber large galaxies by more than ten to one."

P04. (B) In the corona, temperatures reach 1 million to 2 million K. The corona is thought to be heated by magnetic fields, but why the temperature changes so abruptly at the transition between the chromosphere and the corona is not at all clear.

P05. (A) Here the volume is 0.500 ml = 0.500 cm^3. The area of the oil film is $A = \pi r^2 = \pi(2.50)^2 = 19.63\ m^2 = 1.963 \times 10^5\ cm^2$. We can treat the oil film as a very short cylinder, so dividing the volume by the area gives the thickness of the oil film: $h = V/A = 0.500/1.963 \times 10^5 = 2.55 \times 10^{-6}\ cm = 25.5\ nm$.

P06. (D) This is a simple uniformly accelerated motion problem in one dimension. We have some choices about which equations to use, but I'll choose one with time in it:
$x = x_0 + v_0 t + \frac{1}{2}at^2 = 0 + 0 + (0.5)(12.5)(5)^2 = 156$m.

P07. (D) Since this entire problem is in equilibrium, the weight of the window must be equal to the tension in the main cable. Both the main cable tension and the weight are forces entirely in the y-direction. The corner ropes are angled, so they have both horizontal and vertical components to their tension. Using either angled rope, we can calculate its components: $T_{1x} = T_1 cos\theta = (390)\cos(55) = 223.7\ N$ and $T_{1y} = T_1 sin\theta = (390)\sin(55) = 319.5\ N$. The horizontal components of the two corner ropes cancel out since they are equal and in opposite directions.
Noting that the whole system is in equilibrium, the vertical forces on the corner ropes must be equal to the vertical force of the main cable. So, $T_{main} = T_{2y} + T_{1y} = 639\ N$. But since the tension in the main cable equals the weight of the window, then we can conclude: $W = 639\ N = mg$. Finally, $m = \frac{W}{g} = \frac{639}{9.8} = 65.2\ kg$.

P08. (C) This is most easily solved using Conservation of Energy. The block begins with only Gravitational Potential Energy (GPE) and converts that energy into Kinetic Energy (KE). At the top of the bump, there is still some GPE, since we usually take h = 0 to be ground level, and the bump is above that. Setting the energy at the start equal to the energy at the top of the bump: $mgh_0 = mgh_1 + \frac{1}{2}mv^2$. Notice that the mass is in every term, so it cancels, giving: $(9.8)(2.7) = (9.8)(0.8) + \frac{1}{2}v^2$, which leads to $\frac{1}{2}v^2 = 18.62$, or $v = \sqrt{37.24} = 6.10\ m/s$.

P09. (B) First, let's go ahead and calculate the moment of inertia of the rod:
$I = \frac{1}{3}mL^2 = (0.333)(1.5)(1.2)^2 = 0.720\ kgm^2$. To get angular acceleration, we will also need the net torque on the rod. The torque comes from two forces acting on the rod – the applied force and the weight of the rod itself. Pleasantly, the forces in this case are perpendicular to the rod, so the torque is just the product of the force and the distance from the pivot. Also, both forces are directed as to cause rotation in the same direction, so the net torque is the sum of the individual torques. Thus, $\tau = (mg)l_1 + Fl_2 = (1.5)(9.8)(0.6) + (10)(1.0) = 18.82\ Nm$. Note that l_1 is the distance from the pivot to the center of the rod (the center of mass – where the weight is acting on the rod), and l_2 is the distance from the pivot to a point 20cm left of the right end of the rod (a picture is helpful here). Finally, we use the equation: $\tau = I\alpha = 18.82 = (0.720)\alpha$, which gives $\alpha = 26.1\ rad/s^2$.

P10. (D) The period of a mass on a spring is given by $T = 2\pi\sqrt{\frac{m}{k}} = 1.12 = 2\pi\sqrt{\frac{0.100}{k}}$, which gives a spring constant of $k = 3.147\ N/m$. Now using the same equation and the same spring constant with the new mass gives:
$T = 2\pi\sqrt{\frac{0.250}{3.147}} = 1.77\ sec$.

P11. (C) Conservation of energy for an engine gives us: $W = Q_{in} - Q_{out} = 1500 - 900 = 600\,J$ of useful work. Then the efficiency is $e = \frac{W}{Q_{in}} \times 100\% = \frac{600}{1500} \times 100 = 40\%$.

P12. (A) First, we need to combine the three resistors in the parallel group into a single equivalent resistance. $\frac{1}{R_P} = \frac{1}{75} + \frac{1}{60} + \frac{1}{110}$, which leads to $R_P = 25.58\,\Omega$. Then, the remaining resistor is in series with the parallel group, so the total resistance of the circuit is $R_T = 25.58 + 100 = 125.58\,\Omega$. From this we can determine the current provided by the battery: $I_0 = \frac{V}{R_T} = \frac{16.8}{125.58} = 0.13378\,A$. This same current passes through the 100 Ω resistor and through the equivalent resistance of the parallel group. Using Ohm's Law again, we can find the voltage across the parallel group: $V_P = I_0 R_P = (0.13378)(25.58) = 3.422\,V$. For resistors in parallel, the voltage across the group is the same as the voltage across each individual resistor. We can use this to find the current through the 75.0 Ω resistor: $I_{75} = \frac{V_P}{75} = \frac{3.422}{75} = 0.0456\,A = 45.6\,mA$.

P13. (D) A simple application of Coulomb's Law: The magnitude of the force is given by: $F = \left|\frac{kQ_1Q_2}{r^2}\right| = \left|\frac{(9\times10^9)(-80\times10^{-6})(100\times10^{-6})}{(.05-.02)^2}\right| = 8.0\times10^4\,N$. Noting that the signs of the charges are opposite we know the force will be attractive, so the force on the 100μC charge will be towards the other charge, or to the left.

P14. (C) The radius of the circle traced by a charged particle in a magnetic field is given by $R = \frac{mv}{qB}$. We have all of these values, but not all are in the correct units.
First, the mass of the ions: $m = 6u = 6(1.66 \times 10^{-27} kg/u) = 9.96 \times 10^{-27} kg$.
Now, the charge: singly ionized means $q = e = 1.602 \times 10^{-19} C$.
So, $R = \frac{mv}{qB} = \frac{(9.96 \times 10^{-27})(8.50 \times 10^5)}{(1.602 \times 10^{-19})(0.0500)} = 1.06$m.

P15. (E) When the unpolarized light passed through the first polarizer, it not only becomes polarized, but also loses half of its intensity. So, $I_1 = \frac{1}{2}(300) = 150\,W/m^2$. Now, the equation for polarized light passing through a second polarizer is given by Malus' Law: $I_2 = I_1(cos\theta)^2$ where θ is the angle between the different polarization axes. We know $I_2 = 90 = (150)(cos\theta)^2$. So, $cos\theta = 0.7746$, or $\theta = 39°$.

P16. (B) The object location is 4.00cm and the focal length is -20.0cm, so we can get the image location: $\frac{1}{4} + \frac{1}{q} = \frac{1}{-20}$, giving: $q = -3.33cm$. Then the magnification is $M = -\frac{q}{p} = -\frac{-3.33}{4} = 0.833$. So, the final image size is $h' = (0.833)(5.00) = 4.16\,mm$.

P17. (D) Ignoring selection rules means that an atom would be allowed to transition from any excited state down to any lower energy state. There are six ways in which this can happen for the energy diagram shown: $E_1 = 1.70 - 0 = 1.70eV$; $E_2 = 1.70 - 1.20 = 0.50eV$; $E_3 = 1.70 - 1.40 = 0.30eV$; $E_4 = 1.40 - 0 = 1.40eV$; $E_5 = 1.40 - 1.20 = 0.20eV$; $E_6 = 1.20 - 0 = 1.20eV$. Now, we can get the wavelength for each of these transitions by using: $\lambda = \frac{1240\,eVnm}{E}$. Plugging in the various energies of transition, we get wavelengths in nanometers: $\lambda_1 = 729\,nm$; $\lambda_2 = 2480\,nm$; $\lambda_3 = 4130\,nm$; $\lambda_4 = 886\,nm$; $\lambda_5 = 6200\,nm$; $\lambda_6 = 1030\,nm$. These are all of the wavelengths that could be measured from a collection of these atoms. The one choice that is not in this group is 954 nm.

P18. (E) The numbers for Thorium-233 are Z = 90 and A = 233. The chain is Alpha (Z = 2, A = 4), Alpha (Z = 2, A = 4), Beta- (Z = -1, A = 0), Gamma (Z = 0, A = 0), Beta- (Z = -1, A = 0), Alpha (Z = 2, A = 4). So, the final numbers will be Z = 90 – 2 – 2 – (-1) – 0 – (-1) – 2 = 86, and A = 233 – 4 – 4 – 0 – 0 – 0 – 4 = 221. Therefore, the daughter product is (Z = 86, A = 221): Radon – 221.

P19. (A) First notice that this is a speed versus time graph, which means that the slope of the graph will give the acceleration. Also, notice that at all times, the speed is a positive value, which means that the toy car is consistently moving forward, but at an ever-decreasing speed. Combining all of this means that the position of the car is increasing, the speed is decreasing, and the acceleration is negative.

P20. (B) Laboratory data is rarely clean, and this is no exception. The pattern shows the fine interference pattern, but also is affected by the single slit diffraction envelope – causing some bright fringes to vanish or be reduced in intensity. We want to avoid these regions – so I will stick with a measurement made in the bright middle region of the pattern. Ignoring any diminished fringes, we count that the bright middle region contains seven strong fringes (I'll number these as fringe 1 to fringe 7). Using the scale, you can see that the leftmost of these is at about 3.6cm, and the rightmost of these is at about 5.4cm. So, the distance from fringe 1 to fringe 7 is $X = 5.4 - 3.6 = 1.8$cm. Therefore, the average distance between fringes is $y = \frac{X}{(7-1)} = 0.30$cm. Then we can go to the interference formula:

$m\lambda = dsin\theta = (1)(632.8 \times 10^{-9}) = dtan\theta = d\left(\frac{y}{L}\right) = d\left(\frac{0.30 \times 10^{-2}}{1.50}\right) = 0.002d.$

Here I also used the small angle approximation that $sin\theta \approx tan\theta$, which is valid since the value of y is so much smaller than that of L (the distance from the slits to the wall).

Solving for d from this gives: $d = \frac{6.328 \times 10^{-7}}{0.002} = 3.1 \times 10^{-4} m = 0.31\ mm$