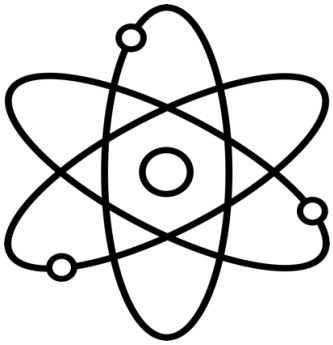
SCIENCE

State • 2015



GENERAL DIRECTIONS:

- DO NOT OPEN EXAM UNTIL TOLD TO DO SO.
- Ninety minutes should be ample time to complete this contest, but since it is not a race, contestants may take up to two hours. 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.
- You may place as many notations as you desire anywhere on the test paper except 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.
- On the back of this page is printed a copy of the periodic table of the elements. You may wish to refer to this table in answering the questions, and if needed, you may use the atomic weights and atomic numbers from the table. Other scientific relationships are listed also.
- Silent hand-held calculators that do not need external wall plugs may be used. Graphing calculators that do not have built-in or stored functionality that provides additional scientific information are allowed. Small hand-held computers are not permitted. Calculators that accept memory cards or memory sticks are not permitted. Each contestant may bring one spare calculator. All memory must be cleared.

SCORING:

All questions will receive 6 points if answered correctly; no points will be given or subtracted if unanswered; 2 points will be deducted for an incorrect answer.

Periodic Table of the Elements

1A 1												3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H 1.008	2A 2																2 He 4.003
3 Li 6.941	4 Be 9.012											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	8B 8	8B 9	8B 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 65.41	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 138.91	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 (272)	112 Cn (285)						

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	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)

Some Standard Properties of Water

property	symbol	value
density of water	ρ_{water}	1.000 g cm^{-3}
density of ice	ρ_{ice}	0.9167 g cm^{-3}
specific heats		
ice	c_{ice}	2.09 J g^{-1} K^{-1}
water	c_{water}	4.184 J g^{-1} K^{-1}
steam	c_{steam}	2.03 J g^{-1} K^{-1}
heat of fusion	ΔH_{fus} or L_f	334 J g^{-1}
heat of vaporization	ΔH_{vap} or L_v	2260 J g^{-1}
index of refraction	n	1.33
autoionization	K_w	1.0×10^{-14}

Pressure		
1 atm	=	760 torr
	=	101325 Pa
	=	14.7 psi
1 bar	=	10^5 Pa
	=	100 kPa

Energy		
1 cal	=	4.184 J
1 L atm	=	101.325 J
1 Cal	=	1 kcal
1 hp	=	746 W
1 eV	=	1.602×10^{-19} J

Various Physical Constants

property	symbol	value
universal gas constant	R	8.314 J mol^{-1} K^{-1} 62.36 L torr mol^{-1} K^{-1} 0.08206 L atm mol^{-1} K^{-1} 1.987 cal mol^{-1} K^{-1}
Planck's constant	h	6.626×10^{-34} J s 4.136×10^{-15} eV s
Planck's reduced constant	$h/2\pi$	1.054×10^{-34} J s 6.582×10^{-16} eV s
Boltzmann constant	k_B	1.38×10^{-23} J K^{-1}
Stefan-Boltzmann	σ	5.67×10^{-8} W m^{-2} K^{-4}
speed of light	c	3.00×10^{8} m s^{-1}
speed of sound (at 20°C)	v_{air}	343 m s^{-1}
acceleration of gravity	g	9.80 m s^{-2}
gravitational constant	G	6.67×10^{-11} N m^2 kg^{-2}
Avogadro's number	N_A	6.022×10^{23} mol^{-1}
elementary charge	e	1.602×10^{-19} C
Faraday	F	96485 C mol^{-1}
Coulomb's law constant	k	8.988×10^{9} N m^2 C^{-2}
Rydberg constant	$\mathbb{R}$	2.178×10^{-18} J

property	symbol	value
electron rest mass	m_e	9.11×10^{-31} kg 0.000549 u 0.511 MeV c^{-2}
proton mass	m_p	1.6726×10^{-27} kg 1.00728 u 938.3 MeV c^{-2}
neutron mass	m_n	1.6749×10^{-27} kg 1.008665 u 939.6 MeV c^{-2}
atomic mass unit	u	1.6605×10^{-27} kg 931.5 MeV c^{-2}
earth mass		5.972×10^{24} kg
earth radius		6.371×10^{6} m
moon mass		7.348×10^{22} kg
sun mass		1.989×10^{30} kg
distance earth-moon		3.844×10^{8} m
distance earth-sun		1.496×10^{11} m
permittivity of free space	ε_0	8.85×10^{-12} F m^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$ T m A^{-1}

Some Other Conversion Factors		
1 in	=	2.54 cm
1 lb	=	453.6 g
1 mi	=	5280 ft = 1.609 km
1 gal	=	4 quarts = 231 in^3 = 3.785 L

Some Average Bond Energies (kJ/mol)							
C–H	413	C–C	346	C–Cl	339	C–N	305
O–H	463	C=C	602	C–Br	285	N=N	418
N–H	391	C≡C	835	O=O	498	H–H	436
C–O	358	C=O	799	C≡O	1072	Br–Br	193
H–Cl	432	S–H	347	N≡N	945	Cl–Cl	242
H–Br	366	H–I	299	C≡N	887	I–I	151

Biology Questions (1 – 20)

1. Herbaceous eudicots differ from woody eudicots in that
   A) In herbaceous eudicots, the apical meristem no longer produces auxin.
   B) In herbaceous eudicots, the lateral meristems are significantly less active.
   C) In herbaceous eudicots, the cork cambium replaces the epidermis with periderm.
   D) In herbaceous eudicots, the production of initials in meristems is by meiosis.

2. Innate immunity in animals is a defense system that is active immediately upon exposure to a pathogen. Adaptive immunity is found only in vertebrates and consists of which of the following items?
   A) Skin, mucous membranes and secretions
   B) Phagocytic cells
   C) Inflammatory response
   D) Cytotoxic cells
   E) All the above are components of the adaptive immunity response.

3. The directional growth in plants in response to touch is called thigmotropism. The rapid leaf movement in the sensitive plant, *Mimosa pudica*, occurs as a result of the loss of turgor in the cells of the pulvinus, a specialized motor organ located at the joint of the leaf. Which of the following explains the rapid loss of turgor in pulvinus cells after stimulation?
   A) Loss of K^+ followed by osmosis out of the cell.
   B) Opening of H^+ pumps followed by osmosis into the cell.
   C) Rapid elongation of cells due to auxin synthesis on one side of the pulvinus.
   D) The rapid redistribution and active transport of statoliths across cells located in the pulvinus.

4. Small non-polar molecules like CO_2 and O_2 can diffuse across the plasma membrane. Large, polar, or charged molecules require a transport protein to move into and out of a cell. The diffusion of gasses limits cell size because:
   A) the laws of physics dictate that diffusion is a slow process
   B) the diffusion gradients require energy inputs provided by cellular respiration
   C) the diffusion rate is proportional to the square of the distance of diffusion
   D) the diffusion rate is inversely proportional the concentration gradient
   E) gasses first must be dissolved in order to undergo diffusion

5. The cardiovascular system in vertebrates is composed of three main types of blood vessels: arteries, capillaries and veins. Choose the correct sequence of blood vessels as they carry blood away from and back to the heart.
   A) Veins, venules, capillaries, arteries
   B) Arterioles, arteries, capillaries, capillary beds, veins, venules
   C) Arteries, capillaries, capillary beds, arterioles, venules, veins
   D) Arteries, arterioles, capillary beds, capillaries, venules, veins
   E) Arteries, arterioles, capillaries, capillary beds, venules, veins

6. After cellular infection, some viruses enter an inactive state called latency. Which of the following is NOT true regarding a dormant virus?
   A) The viral genome continues to be replicated in infected cells.
   B) Cells infected with the dormant virus cease to make most viral proteins.
   C) Viral latency can be broken by environmental conditions.
   D) The dormant virus continues to trigger the adaptive immune response.

7. Complete non-disjunction during meiosis in plants can lead to polyploidy, the doubling (or more) of chromosome sets. The main difference between allopolyploidy and autopolyploidy in plants is that in autopolyploidy the
   A) chromosome sets are found in multiples of 3
   B) chromosome sets arise from 2 different species
   C) chromosome sets arise from 1 species
   D) chromosome sets are the result of self-pollination
   E) chromosome sets are the result of cross-pollination

8. X-inactivation in female mammals insures that females and males have the same effective dose of proteins coded by the X chromosome. Inactivation of the X chromosome involves which of the following processes?
   A) Silencing of the promoters
   B) Inhibition of the transcription factors
   C) Acetylation of nucleosomes
   D) Activation of the XIST gene
   E) Degradation of the histones

9. The efficiency of signal transduction in cell signaling is increased by the presence of _____ which are large relay proteins to which several other relay proteins are simultaneously attached.
   A) Scaffolding proteins
   B) G-protein linked transductors
   C) DAG proteins
   D) Adenylyl cyclases
   E) cAMPases

10. The scientist working with fruit flies who provided the most convincing evidence that chromosomes were responsible for Mendel's 'heritable factors' was
    A) James Watson
    B) Francis Crick
    C) Frederick Griffith
    D) Martha Chase
    E) Thomas Hunt Morgan

11. An evolutionary change in the rate or timing of developmental events is known as
    A) Evodevolution
    B) Homoplasy
    C) Heterochrony
    D) Symplasy
    E) Heteromorphism

12. A plate of ectodermal cells that roll into a hollow tube located dorsally to the notochord in all early embryonic forms in chordates
    A) provides evidence for their shared ancestry
    B) is present at all stages of life
    C) is found only in vertebrates
    D) develops into the bony vertebral column
    E) is a result of convergent evolution

13. In plants, root hairs and trichomes are both derived from which plant tissue system?
    A) Dermal
    B) Ground
    C) Vascular
    D) Xylem
    E) Phloem

14. Hydroponic cultures of plants are grown in mineral solutions without soil. The aerated solution that surrounds the roots must contain abundant dissolved oxygen to prevent which of the following?
    A) Chlorosis of the leaves
    B) Flood tolerance of the roots
    C) Slowing of photosynthesis due to lack of oxygen
    D) Alcoholic fermentation in the roots
    E) Inactivation of proton pumps

15. Homeostasis in animals is a dynamic equilibrium that moderates changes in the internal environment. Which of the following plays the major role in homoeostasis in animals?
    A) Amplified feedback
    B) Dampened feedback
    C) Negative feedback
    D) Positive feedback
    E) Thalamal feedback

16. There are four main feeding mechanisms found in in animals: suspensions feeders, substrate feeders, fluid feeders and bulk feeders. Which of the following play a role in bulk feeding?
    A) Tentacles
    B) Jaws
    C) Baleen
    D) A and B
    E) A, B and C

17. As population density increases, density-dependent mechanisms stop or slow population growth. Which of the following illustrates a density- *independent* regulation of population growth?
    A) Intrinsic physiological factors that delay reproduction.
    B) Predation that increases the death rate.
    C) Production of toxic waste products that increase the death rate.
    D) Competition for resources that decreases the birth rate.
    E) Effects of natural disaster that decreases population size.

18. Measurements of biodiversity include which of the following?
    A) Genetic diversity within a population
    B) Species diversity within a community
    C) Ecosystem diversity with the biosphere
    D) B and C
    E) A, B and C

19. Which of the following accurately portrays the relationship between saturation of fatty acids and plasma membrane fluidity?
    A) As saturation increases, fluidity increases.
    B) As saturation increases, fluidity decreases.
    C) There is no discernable effect of saturation on membrane fluidity.

20. The ATP synthase is a molecular 'mill' that phosphorylates ADP to ATP using the power of a proton gradient in both the chloroplast and the mitochondrion. The ATP synthase has four main parts:
    A) the stator, rotor, rod and mill
    B) the stator, rotor, mill and knob
    C) the stator, mill, knob and rod
    D) the stator, rod, mill and knob
    E) the stator, rod, rotor and knob

Chemistry Questions (21 – 40)

21. Permanganate will oxidize chloride in acidic conditions to produce chlorine gas and manganese(II). The unbalanced reaction is

    $MnO_4^-(aq) + Cl^-(aq) \longrightarrow Mn^{2+}(aq) + Cl_2(g)$

    80 mL of 0.0500 M $KMnO_4$ is poured into 320 mL of 0.0750 M KCl. The resulting chlorine gas is collected at 722 torr and 28.0°C. What is the volume of the collected chlorine gas?
    A) 325 mL
    B) 195 mL
    C) 173 mL
    D) 312 mL
    E) 260 mL
    F) 624 mL

22. Step 1. Balance the reaction:

    $CS_2 + O_2 \longrightarrow CO_2 + SO_2$

    Step 2. What is the percent yield of this reaction when 62.3 mg of CS_2 reacts with excess oxygen to give 86.2 mg of SO_2?
    A) 94.8 %
    B) 82.2 %
    C) 87.5 %
    D) 79.1 %
    E) 91.4 %
    F) 98.3 %

23. Use a table of bond energies to calculate the approximate heat of reaction between methanol and carbon monoxide to form acetic acid.

$CH_3OH + CO \longrightarrow CH_3COOH$

A) –390 kJ
B) –183 kJ
C) +296 kJ
D) –73 kJ
E) –117 kJ

24. Benzene has a normal boiling point of 80°C and a heat of vaporization of 34 kJ/mol. If the applied pressure is changed to 100 torr, at what temperature will benzene begin to boil?

A) 27°C
B) 32°C
C) 18°C
D) 43°C
E) 51°C
F) 65°C

25. Given the following two reactions and the associated enthalpies of reaction:

reactions	ΔH_{rxn}
$H_2(g) + Cl_2(g) \longrightarrow 2\ HCl(g)$	–184.6 kJ
$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$	–483.6 kJ

Determine the value of ΔH_{rxn} for the following reaction:

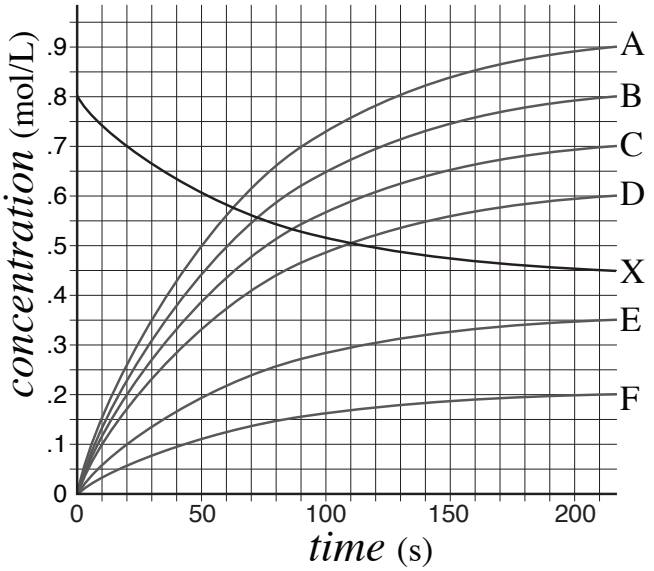
$4\ HCl(g) + O_2(g) \longrightarrow 2\ Cl_2(g) + 2\ H_2O(g)$

A) –299.0 kJ
B) –598.0 kJ
C) –114.4 kJ
D) +299.0 kJ
E) +598.0 kJ
F) +114.4 kJ

26. A weak acid, HX, is dissolved into water at a concentration of 0.30 *m*. The freezing point of this solution was precisely measured to be –0.614°C. The freezing point depression constant for water is 1.86°C/*m*. What is the percent ionization of this weak acid?

A) 5%
B) 33%
C) 42%
D) 10%
E) 50%
F) 25%

27. Below are several plots of concentration vs time. The plot labeled X is for the concentration of X in the reaction: X ⟶ 2Y. Which one of the plots A-F is the correct plot for the concentration of Y during the same reaction?



28. Tris(hydroxymethyl)aminomethane is commonly known as "tris" and has a K_b equal to 1.2×10^{-6}. The formula for tris is $(HOCH_2)_3CNH_2$. 50 mL of 0.15 M hydrobromic acid is added to 200 mL of 0.17 M tris. What is the pH of the resulting 250 mL of solution?

A) 7.53
B) 8.63
C) 8.74
D) 8.08
E) 7.42
F) 10.65

29. A concentration cell is set up for a generic metal and its cation:

$M(s) \mid M^{2+}(aq, 0.88\ M) \parallel M^{2+}(aq, 0.00011\ M) \mid M(s)$

What is the potential for this cell as written?

A) –115 mV
B) –245 mV
C) +230 mV
D) +115 mV
E) +245 mV
F) –230 mV

30. The non-ionized form of an indicator is yellow while the ionized form is blue. The K_a for this indicator is 3.2×10^{-5}. One drop of this indicator is added to a 0.051 M solution of hypobromous acid (HOBr) which has a K_a of 2.3×10^{-9}. Which of the following best describes the color of this solution?

A) blue
B) yellow-green
C) green
D) blue-green
E) yellow-orange
F) yellow

31. What is the wavelength of light emitted when an electron in a hydrogen atom transitions from $n = 6$ to $n = 2$.

A) 128 nm C) 639 nm E) 411 nm
B) 274 nm D) 1250 nm F) 927 nm

32. According to quantum mechanics and atomic theory, which one of the following orbitals does not theoretically exist?

A) 7*s* C) 8*p* E) 6*h*
B) 6*d* D) 5*g* F) 3*f*

33. The following kinetic data was collected for the reaction: A + 2B + C ⟶ D

exp	[A]	[B]	[C]	rate of formation of D (M/s)
1	0.15	0.10	0.20	1.25×10^{-3}
2	0.15	0.20	0.20	1.25×10^{-3}
3	0.15	0.30	0.40	2.50×10^{-3}
4	0.24	0.40	0.25	4.00×10^{-3}

Which of the following equations is the rate law for this reaction for the given units?

A) 0.0417 [A][C] E) 4.17 $[A][B]^2[C]$
B) 0.417 [A][B][C] F) 0.556 $[A]^2[B]$
C) 0.0417 $[A]^2[C]$ G) 0.278 $[A]^2[C]$
D) 0.625 $[B]^2[C]$ H) 0.208 $[A][C]^2$

34. A solution of 0.10 M HF ($K_a = 7.2\times10^{-4}$) is adjusted to a pH of exactly 1.50. What is the solubility of of CaF_2 ($K_{sp} = 3.9\times10^{-11}$) in this solution?

A) 16.7 mg/L D) 587 mg/L G) 72.0 mg/L
B) 305 ng/L E) 465 µg/L H) 614 mg/L
C) 614 µg/L F) 587 µg/L I) 3.9 ng/L

35. The following is directly from a table of standard potentials ($E°$):

$Cd^{2+} + 2e^- \rightleftharpoons Cd(s)$ –0.402 V

$CdC_2O_4(s) + 2e^- \rightleftharpoons Cd(s) + C_2O_4^{2-}$ –0.522 V

Calculate the value for K_{sp} for CdC_2O_4.

A) 8.8×10^{-5} D) 2.3×10^{-18}
B) 9.4×10^{-3} E) 1.1×10^{4}
C) 5.9×10^{-32} F) 1.5×10^{-9}

36. *Ice vs Steam*: A mass ratio of 4:1 of ice to steam is put into an insulated container. The ice is introduced at –15°C and the steam at 115°C. What is the temperature in the container after thermal equilibrium is reached?

A) 20.6°C D) 68.2°C
B) 59.6°C E) 40.4°C
C) 35.3°C F) 13.9°C

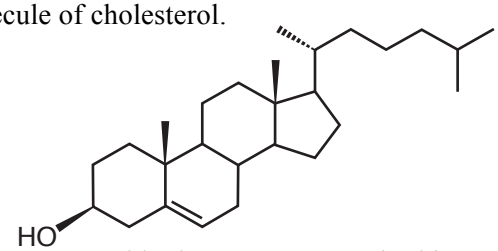
37. At 600 K, $K_p = 5.20$ for the following reaction:

$3Fe(s) + 4H_2O(g) \rightleftharpoons 4H_2(g) + Fe_3O_4(s)$

30.74 g of H_2O and excess iron is added and sealed into a 12-liter reaction container. The container is then heated to 600 K and equilibrium is reached. What is the pressure of hydrogen gas at this temperature in this reaction mixture?

A) 2.79 atm D) 5.87 atm
B) 4.87 atm E) 3.85 atm
C) 5.37 atm F) 4.21 atm

38. The following is the abbreviated line structure for a molecule of cholesterol.



How many total hydrogen atoms are in this structure? Your total should include both the shown hydrogen atoms and any implied hydrogen atoms.

A) 52 C) 39 E) 45
B) 43 D) 46 F) 49

39. The reaction, A ⟶ 2B, is found to be 2nd order in reactant A. The half-life for this reaction when A is initially 0.64 M, is 12.5 minutes. If the concentration of A is now started at 0.256 M with no B present. How long will it take for the product B to increase from 0 to 0.448 M ?

A) > 10 hr C) 37.5 min E) 87.5 min
B) 3.65 hr D) 4.32 hr F) < 5 min

40. Identify the molecule that has the most polar bonds and then the molecule with the greatest dipole moment from this list:

F_2 CS_2 CH_3I NH_3 PF_5

A) F_2 most polar bonds ; NH_3 greatest dipole
B) PF_5 most polar bonds and the greatest dipole
C) PF_5 most polar bonds ; CH_3I greatest dipole
D) NH_3 most polar bonds and the greatest dipole
E) PF_5 most polar bonds ; NH_3 greatest dipole

Physics Questions (41 – 60)

On this contest ***i***, ***j*** and ***k*** are the unit vectors in the $+x$, $+y$ and $+z$ directions respectively, and unless otherwise indicated, you may neglect air resistance in every problem.

41. According to Tyson, which state declared on March 8, 2007 that Pluto was a planet within state borders?

A) Arizona
B) California
C) Nevada
D) New Mexico
E) Texas

42. According to Tyson, the American Dialect Society "[upgraded] the status of the word Pluto to a verb" to mean which of the following:

A) to act as a laxative
B) to demote or devalue
C) to inflate
D) to move far away
E) to throw away

43. According to Tyson, as voted in August 2006 by the general assembly of the International Astronomical Union (IAU) that overturned the Planet Definition Resolution proposal by the Planet Definition Committee - Pluto was officially a dwarf planet because it failed which new criterion?

A) A planet must be round.
B) A planet must dominate the mass of its orbital zone.
C) A planet must have a moon.
D) A planet must have rings.
E) A planet must orbit the Sun.

44. According to Tyson, in July 2008 the Executive Committee of the IAU Committee on Small Body Nomenclature approved a proposal for what name to classify "all dwarf planets that one might find orbiting beyond Neptune"?

A) asteroids
B) icy dwarf planets
C) main plane planets
D) plutoid
E) trans-Neptunian object

45. For a particle moving in one dimension along the x-axis in which the acceleration a is a function of the position x that is given by $a(x) = 3.0x$, where x is in meters and a is in meters/second^2. If the velocity is zero at $x = 1.0$ m, then what is the velocity at $x = 5.0$ m?

A) 3.5 m/s
B) 4.9 m/s
C) 8.5 m/s
D) 8.7 m/s
E) 42 m/s

46. An archer stands on a boulder and fires an arrow from a height of 6.50 m above the level ground below the boulder. If the initial velocity of the arrow fired from the bow is 53.0 m/s at an angle of 20.0° above the horizontal, then what is the horizontal distance that the arrow travels?

A) 92.1 m
B) 107 m
C) 190 m
D) 201 m
E) 220 m

47. A 2500 kg truck is traveling uphill on a road that makes an angle of 23.0° with the horizontal. The coefficient of static friction between the truck tires and the road is 0.920. If the truck is speeding up, then what is the magnitude of the maximum acceleration of the truck?

A) 4.47 m/s^2
B) 5.50 m/s^2
C) 8.31 m/s^2
D) 12.1 m/s^2
E) 12.5 m/s^2

48. A 5.0 kg particle starts from rest at $x = 0.025$ m and moves along the x-axis under a force $F(x) = 8.0 + 2.0x - 4.0x^2$, where x is in meters and F is in newtons. What is the work done by the force as the particle moves from $x = 0.025$ m to $x = 2.75$ m?

A) 1.6 J
B) 1.8 J
C) 20 J
D) 42 J
E) 57 J

49. A pendulum consists of a string of length L with a mass m attached at one end. The other end of the string is freely attached to a support. The mass is held such that the string is horizontal before being released from rest. A peg is located a distance R up from the lowest point in the motion of the mass. If the string is to stay taut as the mass swings around the peg in a full circle, then what is the maximum value of R? You may model the mass as a point mass and neglect the thickness of the peg.

A) $(2/5)L$
B) $(1/2)L$
C) $(3/5)L$
D) $(4/5)L$
E) L

50. A 25.0 g ball hits a vertical wall. The ball is in contact with the wall for 1.25 ms before bouncing off with the same speed and a reversed horizontal component of the velocity. The ball moves with a speed of 9.50 m/s and makes an angle of 30.0° with the normal to the wall both before and after the collision. What is the magnitude of the average, net, horizontal force exerted on the ball by the wall?

A) 0.00 N
B) 219 N
C) 238 N
D) 329 N
E) 411 N

51. A harmonic, transverse wave on a string has the following wave function: $y(x,t) = (4.25\text{mm})\sin(27.3x + 252t)$, where x is in meters and t is in seconds. What is the wave speed?

A) 1.08×10^{-1} m/s
B) 1.16×10^{-1} m/s
C) 1.07×10^{0} m/s
D) 9.23×10^{0} m/s
E) 6.88×10^{3} m/s

52. How much heat is released when 250 g of steam at 175°C changes to 250 g of ice at 0.00°C? Given the following data about water: density = 1,000 kg/m^3, specific heat of ice = 2.05 kJ/(kg · K), specific heat of water = 4.18 kJ/(kg · K), specific heat of steam = 2.02 kJ/(kg · K), latent heat of fusion = 333.5 kJ/kg, and latent heat of vaporization = 2257 kJ/kg.
    A) 143 kJ
    B) 224 kJ
    C) 226 kJ
    D) 457 kJ
    E) 790 kJ

53. A nonconducting sphere with a radius of 9.0 cm has a uniform volume charge density of +625 nC/m^3. What is the magnitude of the electric field at a distance of 6.0 cm from the center of the sphere?
    A) 0.0×10^{0} N/C
    B) 1.3×10^{-8} N/C
    C) 2.1×10^{-1} N/C
    D) 1.7×10^{1} N/C
    E) 1.4×10^{3} N/C

54. A 2.4 μF capacitor is charged to 60 V. After being fully charged the capacitor is disconnected from the voltage source and is connected to a completely discharged second capacitor without losing any charge. If the final voltage across the 2.4 μF capacitor is 20 V, then what is the capacitance of the second capacitor?
    A) 1.2 μF
    B) 2.4 μF
    C) 4.8 μF
    D) 7.2 μF
    E) 9.6 μF

55. A particle has mass m, charge q, and moves perpendicular to a uniform magnetic field B in a circular orbit with radius R. What is the kinetic energy of the particle?
    A) qBR
    B) $q^2B^2R^2$
    C) $(qBR)/(2m)$
    D) $(q^2B^2R^2)/(2m)$
    E) $(mq^2B^2R^2)/2$

56. A long solenoid has 75 turns/cm and carries a 5.0 A current. The solenoid is filled with iron and has a magnetic field with a magnitude of 2.34 T at the center of the solenoid. What is the magnitude of the magnetization of the iron?
    A) 4.7×10^{-2} A/m
    B) 3.7×10^{4} A/m
    C) 8.8×10^{4} A/m
    D) 1.8×10^{6} A/m
    E) 1.9×10^{6} A/m

57. A laser pulse has an average energy of 30 J and a beam radius of 1.5 mm. The pulse last for 12 ns. Determine the average energy density within the pulse.
    A) 1.2×10^{0} J/m^3
    B) 8.8×10^{2} J/m^3
    C) 1.8×10^{3} J/m^3
    D) 5.9×10^{5} J/m^3
    E) 1.2×10^{6} J/m^3

58. In a double-slit experiment in which the slits are each 12.0 μm wide and have a center to center separation of 24.0 μm that is illuminated with 600 nm light and the interference pattern is viewed on a screen that lies 4.00 m away from the center of the slits. If a point P lies 70.0 cm away from the center of the pattern on the screen, then what is the ratio of the intensity at point P to the intensity at the center of the pattern?
    A) 2.60×10^{-4}
    B) 7.43×10^{-3}
    C) 8.30×10^{-3}
    D) 2.26×10^{-1}
    E) 8.95×10^{-1}

59. A telescope that has a circular aperture with a diameter of 250 inches is used to image a double star 8.0 light-years away. If light with a wavelength of 625 nm is used, then what is the minimum distance between the two stars so the image will be resolved? Assume ideal viewing conditions.
    A) 7.5×10^{7} m
    B) 1.6×10^{8} m
    C) 6.1×10^{9} m
    D) 9.1×10^{9} m
    E) 4.7×10^{10} m

60. The probability of muon decay is $P(t) = 1 - e^{-t/\tau}$, where τ is the mean proper lifetime which is 2.12 μs. If a muon is created 9000 m above the surface of the Earth, then what is the probability that a muon traveling at 0.980*c* will make it to the surface of the Earth?
    A) 5.36×10^{-5}%
    B) 5.65%
    C) 50.0%
    D) 94.3%
    E) 100% (to 3 significant digits)

UIL HIGH SCHOOL SCIENCE CONTEST

Contestant Answer Sheet

Contestant # _____ 9 10 11 12 A 2A 3A 4A 5A

CONTESTANT GRADE LEVEL *CONFERENCE*

PLEASE WRITE ANSWERS WITH CAPITAL LETTERS

1. _____	21. _____	41. _____
2. _____	22. _____	42. _____
3. _____	23. _____	43. _____
4. _____	24. _____	44. _____
5. _____	25. _____	45. _____
6. _____	26. _____	46. _____
7. _____	27. _____	47. _____
8. _____	28. _____	48. _____
9. _____	29. _____	49. _____
10. _____	30. _____	50. _____
11. _____	31. _____	51. _____
12. _____	32. _____	52. _____
13. _____	33. _____	53. _____
14. _____	34. _____	54. _____
15. _____	35. _____	55. _____
16. _____	36. _____	56. _____
17. _____	37. _____	57. _____
18. _____	38. _____	58. _____
19. _____	39. _____	59. _____
20. _____	40. _____	60. _____

BIOLOGY SCORE	**CHEMISTRY SCORE**	**PHYSICS SCORE**

OVERALL SCORE: _____

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
STATE • 2015

1.	B	21.	E	41.	D
2.	D	22.	B	42.	B
3.	A	23.	D	43.	B
4.	C	24.	A	44.	D
5.	E	25.	C	45.	C
6.	D	26.	D	46.	D
7.	C	27.	C	47.	A
8.	D	28.	B	48.	A
9.	A	29.	A	49.	A
10.	E	30.	D	50.	D
11.	C	31.	E	51.	D
12.	A	32.	F	52.	E
13.	A	33.	G	53.	E
14.	D	34.	C	54.	C
15.	C	35.	A	55.	D
16.	D	36.	B	56.	D
17.	E	37.	F	57.	E
18.	E	38.	D	58.	B
19.	B	39.	B	59.	D
20.	E	40.	E	60.	B

UIL HIGH SCHOOL SCIENCE CONTEST
SOLUTIONS

CHEMISTRY

21. (E) $2MnO_4^- + 10Cl^- + 16H^+ \longrightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$
ratio Cl_2 to MnO_4^- is 5/2
80mL x .05M = 4 mmol (limiting, needs 20 mmol Cl^-)
320mL x 0.075M = 24 mmol (excess by 4 mmol)
722/760 = 0.95 atm
4 mmol (5/2) = 10 mmol Cl_2 (0.01 mol Cl_2)
$V = nRT/P$ = .01(.08206)(301.15)/.95 = 0.26013 L
V = 260 mL

22. (B) $CS_2 + 3\ O_2 \longrightarrow CO_2 + 2\ SO_2$
ratio SO_2 to CS_2 is 2/1
62.3/76.215 = 0.8181 mmol CS_2
0.8181 (2/1) = 1.636 mmol SO_2 (matches 100% yield)
86.2/64.07 = 1.3454 mmol actual yield
1.3454/1.636 x 100% = 82.2% yield

23. (D) Break(+):
C-O, C≡O = 1072
Make(–): C-C = 346, C=O = 799, C-O
C-O's cancel
+1072 -346 -799 = -73

24. (A) Use Arrhenius equation:
ln(760/100) = 34000/8.314(1/T – 1/353.15)
2.028 = 4089.5(1/T – 0.002832)
1/T = 2.028/4089.5 + .002832 = 0.0033276
T = 300.5 K = 27.4°C

25. (C) Flip and double the first. Leave second as is. ADD
$4\ HCl(g) \longrightarrow \cancel{2\ H_2(g)} + 2\ Cl_2(g)$ +369.2 kJ
$\cancel{2\ H_2(g)} + O_2(g) \longrightarrow 2\ H_2O(g)$ –483.6 kJ
giving –114.4 kJ

26. (D) $m_{actual} = \Delta T_f/K_f$ = 0.614/1.86 = 0.33 m
0.33/0.30 = 1.10 ⟶ 10% ionized

27. (C) The X drops from .80 to .45 on the plot which is a decrease of .35 M. The Y will increase from zero to double that which is .70 and matches plot C.

28. (B) pKb = -log(1.2e-6) = 5.9208 tris is B
50(.15) = 7.5 mmol H+ 200(.17) = 34.0 mmol B
34 – 7.5 = 26.5 mmol B left and 7.5 mmol BH+ made
pKa = 14-pKb = 14 – 5.9208 = 8.0792
pH = pKa + log(B/BH+) = 8.0792 + log(26.5/7.5)
pH = 8.0792 + 0.5482 = 8.6274

29. (A) The standard potential is zero (same ½ reaction on each side). Left side is anode and therefore the .88 M cation is a product of the reaction. Use Nernst equation:
E = 0 – 0.0257/2 ln(.88/.00011) = –0.115 V

30. (D) The pK_a for indicator is 4.49 which is where it would be green (50/50 mix of yellow and blue). The acid pH is calculated: $[H+] = \text{sqrt}(2.3 \times 10^{-9} \cdot 0.051) = 1.08 \times 10^{-5}$ which gives a pH of 4.97 which puts the indicator in a ratio of 3:1 of blue:yellow. That will give a color of blue-green.

UIL HIGH SCHOOL SCIENCE CONTEST
SOLUTIONS

31. (E) The Rydberg equation: $\Delta E = R(1/n^2 - 1/n^2)$
$\Delta E = 2.178e\text{-}18(1/2^2 - 1/6^2) = 2.178e\text{-}18(0.2222)$
$\Delta E = 4.84e\text{-}19$ J $\lambda = hc/\Delta E$
$\lambda = 6.626e\text{-}34(3e8)/4.84e\text{-}19$
$= 4.11e\text{-}7$ m $= 411$ nm

32. (F) Quantum number rules:
$n = 1, 2, 3, 4, \ldots$
$\ell = 0, 1, 2, 3, \ldots$ (n-1) corresponding to letters
$= s, p, d, f, g, h, i, \ldots$
You cannot have $n = 3$ paired with $\ell = 3$ (f)

33. (G) Comparing 1 and 2 we know B is zero order.
Comparing 1 and 3 we know C is first order.
Comparing 1 and 4 we know A is 2nd order.
Solve for k = rate/$[A]^2[C]$ = .00125/(.15^2 .2)
$k = 0.278$

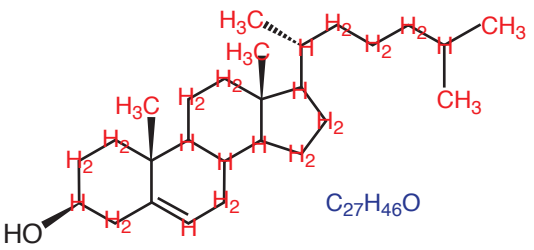
34. (C) $K_a = [H^+]x/.1\text{-}x$ where x is $[F^-]$
$[F^-]=7.2\times10^{-4}(.1)/(10^{-1.5}+7.2\times10^{-4})= 0.0022262$ M
$[Ca^{2+}]=3.9\times10^{-11}/(.0022262)^2= 7.870\times10^{-6}$ M
7.870×10^{-6} (78.08g/mol) $= 6.145\times10^{-4}$ g/L
$\times1000 = 0.614$ mg/L $= 614$ µg/L

35. (A) $E° = -.522 - (-.402) = -0.120$ V
$RT\ln K = nFE°$ $K = \exp(nFE°/RT)$
$K = \exp\{2(96485)(-.120)/(8.314\cdot298.15)\}$
$K = \exp\{-23156.4/2478.8\} = 8.769\times10^{-5}$

36. (B) Easiest to use 4g ice and 1g steam
Take both to 100°C water as a point of reference
ice: 15(2.09)+334+418.4 ×4 = 3135 J
steam: 15(2.03)+2260 = 2290.45 J
difference is : 844.55 J on the cold side of 100°C
844.55/(4.184·5g) = 40.4°C down from 100°C
which gives 59.6°C

37. (F) 30.74/18.016 = 1.706 mol H_2O
$P = nRT/V = 1.706(0.08206)(600)/12 = 7.00$ atm
$K_p=P_{H2}{}^4/P_{H2O}{}^4=[x/(7\text{-}x)]^4$
$(5.2)^{1/4} = x/(7\text{-}x)$ $1.51(7) = 2.51x$ $x = 4.21 = P_{H2}$

38. (D) Structure with implied C's and H's. H = 46



UIL HIGH SCHOOL SCIENCE CONTEST
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39. (B) 2nd order $k = 1/[A]_0 t_{1/2} = 1/.64(12.5) = 0.125$
product at .448 M means .224 M of reactant gone
.256 - .224 = 0.032 for A at that time.
(1/.032 – 1/.256)/.125 = 218.75 min = 3.65 hr

40. (A) Periodic table trends and molecular geometry.
The P-F bond is the most polar bonds of those listed (biggest EN difference). Symmetry zeros the dipole for PF_5, CS_2, and F_2. The NH_3 will have a bigger dipole moment than CH_3I.

PHYSICS

41. (D) "New Mexico is longtime home of Pluto discoverer Clyde Tombaugh… The state legislature felt that the IAU had unjustifiably dissed Pluto and, by association, their great state. So on March 8, 2007, their 48th legislature, in a bill introduced by Representative Joni Marie Gutierrez, passed a Joint Memorial declaring Pluto a planet within state borders…"

42. (B) "While astrophysicists were downgrading the cosmic object we call Pluto, the American Dialectic Society, which is more than a century old, was upgrading the status of the word Pluto to a verb, making it their 17th annual "Word of the Year" for 2006:

to pluto / to be plutoed: to demote or devalue someone or something …"

43. (B) "Plutophiles had about a week to rejoice before learning the sad news that Pluto fails a new criterion – that a legitimate planet must also dominate the mass of its orbital zone."

44. (D) "At a July 2008 meeting in Oslo, Norway, the Executive Committee of the IAU approved a proposal from the IAU Committee on Small Body Nomenclature for the name *plutoid* to classify all dwarf planets that one might find orbiting beyond Neptune."

45. (C) By $a = dv/dt = (dv/dx)(dx/dt) = v(dv/dx) \Rightarrow \int v\,dv = \int a\,dx = \int 3x\,dx \Rightarrow [v^2/2|^v_0 = [(3/2)x^2|^5_1$
$\Rightarrow v = [3(5)^2 - 3(1)^2]^{1/2} = 8.5$ m/s

46. (D) By $y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \Rightarrow 0 = 6.5 + 53(\sin 20°)t - 4.9t^2 \Rightarrow t = 4.029$ s
& $x = x_0 + v_{0x}t = 0 + 53(\cos 20°)\,4.029 = 201$ m

47. (A) From N2L & the FBD of the situation: $\Sigma \boldsymbol{F}_\perp = +F_N - F_{G\perp} = 0 \Rightarrow F_N = mg\cos 23°$
& $\Sigma \boldsymbol{F}_\parallel = +F_{fs} - F_{G\parallel} = ma \Rightarrow \mu_s mg\cos 23° - mg\sin 23° = ma$
$\Rightarrow a = (9.8)[(0.92)\cos 23° - \sin 23°] = 4.47$ m/s^2

48. (A) By $W = \int F\,dx = \int(8 + 2x - 4x^2)\,dx = [8x + x^2 - (4/3)x^3|^{2.75}_{0.025} = 1.65$ J

49. (A) From N2L and the FBD at the top of the circle as it goes around the peg: $\Sigma \boldsymbol{F}_c = +F_T + F_G = ma_c$, for minimum speed: $0 + mg = mv_{min}^2/R \Rightarrow v_{min} = (gR)^{1/2}$ & by conservation of mechanical energy with the zero of gravitational potential energy at the top of the circle:
$E_0 = E_{top} \Rightarrow 0 + mg(L - 2R) = \frac{1}{2}m(gR) + 0 \Rightarrow R = (2/5)L$

50. (D) By $\Sigma \boldsymbol{F}_{avg,x} = \Delta \boldsymbol{p}_x/\Delta t = 2(0.025)(9.5\cos 30°)/(0.00125) = 329$N

51. (D) $v = \omega/k = 252/27.3 = 9.23$ m/s

UIL HIGH SCHOOL SCIENCE CONTEST
SOLUTIONS

52. (E) $Q = mc_{steam}\Delta T_{steam} - mL_V + mc_{water}\Delta T_{water} - mL_F$
= (0.25)(2.02)(100−175) − (0.25)(2257) + (0.25)(4.18)(0−100) − (0.25)(333.5) = -790 kJ,
so 790 kJ of heat is released

53. (E) By Gauss' law: $\int \boldsymbol{E}\cdot d\boldsymbol{a} = Q_{enc}/\varepsilon_0 \Rightarrow E(4\pi r^2) = \rho[(4/3)\pi r^3]/\varepsilon_0$
$\Rightarrow E = [\rho r]/[3\varepsilon_0]$ = [(625E-9)(0.06)]/[3(8.85E-12)] = 1.4E+3 N/C

54. (C) Q_0 = (2.4E-6)(60) = 144μC & Q_1 = (2.4E-6)(20) = 48μC, with $Q_0 = Q_1 + Q_2 \Rightarrow Q_2$ = 96μC,
thus C = (96E-6)/(20) = 4.8μF

55. (D) By $\Sigma \boldsymbol{F}_c = +F_B = ma_c \Rightarrow |q|vB \sin 90° = mv^2/R \Rightarrow mv = |q|BR \Rightarrow K = \frac{1}{2}mv^2 = (q^2B^2R^2)/(2m)$

56. (D) $B_{app} = \mu_0 nI$ = (4πE-7)(7500)(5) = 4.71E-2 T, with $B = B_{app} + \mu_0 M$
$\Rightarrow M$ = (2.34−4.71E-2)/(4πE-7) = 1.8E+6 A/m

57. (E) By $I = U_{avg}/(A\cdot t) = u_{avg}c \Rightarrow u_{avg} = U_{avg}/[A\cdot t\cdot c]$ = 30/[π(1.5E-3)^2(12E-9)(3E+8)] = 1.2E+6 J/m^3

58. (B) With calculator in radian mode: $\theta = \tan^{-1}(y/L) = \tan^{-1}(0.7/4)$ = 0.1732 rad,
then $\alpha = [\pi a/\lambda] \sin\theta$ = [π(12E-6)/(600E-9)] sin(0.1732 rad) = 10.83 rad
& $\beta = [\pi d/\lambda] \sin\theta$ = [π(24E-6)/(600E-9)] sin(0.1732 rad) = 21.66 rad
$\Rightarrow I_P/I_m = [(\sin\alpha)/\alpha]^2[\cos\beta]^2$ = [(sin(10.83 rad))/(10.83 rad)]^2[cos(21.66 rad)]^2 = 7.43E-3

59. (D) Using the small angle approximation and the Raleigh criterion for resolution:
$s = R\theta_{min} = R(1.22\lambda/D)$ = [(8)(3E+8)(1.556E+7)]{(1.22)(625E-9)/[(250)(2.54)(1/100)]} = 9.1E+9 m

60. (B) With $\gamma = [1-(v/c)^2]^{-½}$ = [1−(0.98)^2]$^{-½}$ = 5.025,
then $t = L_0/v = L/[\gamma v]$ = (9000)/[(5.025)(0.98)(3E+8)] = 6.092E-6 s
& (prob. of making it) = 1 − (prob. of decay) = $e^{-(t/\tau)} = e^{-(6.092E-6/2.12E-6)}$ = 0.0565 ⇒ 5.65%