Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

CHEMISTRY TEST – REGIONAL

Chemistry Test Production Team

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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. One oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

Be sure ovals are marked as ● , not ⊙ , ◐ , ◑ , etc.

If you wish to change an answer, erase your first mark completely before marking your new choice.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

Time: 40 Minutes Number of Questions: 40

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Periodic Table of the Elements

1A	2A											3A	4A	5A	6A	7A	8A
1 H 1.008																	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											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 47.88	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 72.59	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 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226	89 Ac** (227)	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

*Lanthanides	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
**Actinides	90 Th 232.0	91 Pa (231)	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 (260)

Potentially Useful Information

$q = m \bullet c_s \bullet \Delta T$

$\Delta T_f = i \bullet K_f \bullet m$

$\Delta T_b = i \bullet K_b \bullet m$

$S_{gas} = k_H \bullet P_{gas}$

$P_{solvent} = X_{solvent} \bullet P°_{solvent}$

$k = Ae^{-Ea/RT}$

$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt$

$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$

$[A]_t - [A]_0 = -kt$

$\ln\left(\frac{k_2}{k_1}\right) = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H_{rxn}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$pH = -\log [H_3O^+]$

$pOH = -\log [OH^-]$

$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$

$\Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

$\Delta E = B\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\Delta G° = -nF\varepsilon°$

$c = \lambda\nu$

$\Pi = MRT$

$\Delta E = h\nu$

$F = 96485$ C/mol

$K_w = 1.0 \times 10^{-14}$

$R = 0.08206$ L atm/mol K; 8.3145 J/mol K

$B = -2.18 \times 10^{-18}$ J

1.0 kg = 2.2 lb

$N_A = 6.022 \times 10^{23}$

1.0 in = 2.54 cm

1 atm = 101,325 Pa = 1.01325 bar

1 lb = 453.59 g

1 J = 1 N • m = 1 kg • m^2 • s^{-2} = 0.239 cal

$c = 2.998 \times 10^8$ m/s

$h = 6.626 \times 10^{-34}$ J·s

Assume all gases behave ideally unless specifically told to do otherwise
Assume all solutions are aqueous and at 25 °C unless specifically told otherwise
Assume all gases are at STP unless specifically told otherwise

Simple Rules for the Solubility of Salts in Water

1. Most nitrates are soluble
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+, Pb^{2+}, and Hg_2^{2+}.
4. Most sulfates are soluble with the exception of Ba^{2+}, Pb^{2+}, Hg_2^{2+}, and Ca^{2+}
5. Most hydroxide salts are only slightly soluble with the exception of Group 1 hydroxides. Group 2 (Ba^{2+} to Ca^{2+}) are slightly soluble.
6. Most sulfides, carbonates, chromates, and phosphates are only slightly soluble.

Academic Challenge
Chemistry Test (Regional) – 2019

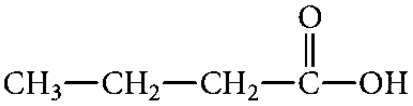
1. Identify an alpha particle.

   A. $_{-1}^{0}e^{-}$ B. $_{0}^{1}n$ C. $_{+1}^{0}e$ D. $_{0}^{0}\gamma$ E. $_{2}^{4}He^{2+}$

2. Which of the following is not a pure substance?

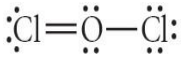
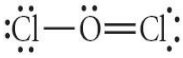
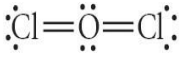
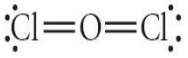
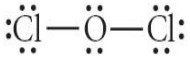
   A. 24 carat gold jewelry
   B. copper wire used for home wiring
   C. orange juice grown in organic farming
   D. aluminum foil used in baking
   E. all of the above

3. Name the following compound.



   A. propyl butanoate
   B. butanoic acid
   C. 1-butanal
   D. 1-butanoate
   E. propyl methanoate

4. Choose the best Lewis structure for OCl_2.

   A. 
   B. 
   C. 
   D. 
   E. 

5. What pressure will 14.0 g of CO exert in a 3.5 L container at 75 °C?

   A. 5.0 atm B. 4.1 atm C. 6.4 atm D. 1.1 atm E. 2.3 atm

6. Which of the following processes have a $\Delta S > 0$?

   A. $CH_3OH(l) \rightarrow CH_3OH(s)$
   B. $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$
   C. $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3\ H_2(g)$
   D. $Na_2CO_3(s) + H_2O(g) + CO_2(g) \rightarrow 2\ NaHCO_3(s)$
   E. All of the above processes have a $\Delta S > 0$

7. Which one of the following compounds behaves as an acid when dissolved in water?

   A. CaO B. HF C. C_2H_6 D. NaO E. NH_3

8. Substances with a definite shape and volume are in the _____ phase.

   A. solid B. liquid C. gas D. plasma E. solution

9. Write the name for $Sn(SO_4)_2$.

   A. tin(I) sulfite B. tin(I) sulfate C. tin sulfide D. tin(II) sulfite E. tin(IV) sulfate

10. Which of the following is NOT a standard state for the purpose of thermodynamic calculations?

    A. For a solid, it is often 25 °F.
    B. For a liquid, it is often 25 °C.
    C. For a gas, it is 1 atm.
    D. For a solution, it is 1 M.
    E. For a liquid, it is 1 atm.

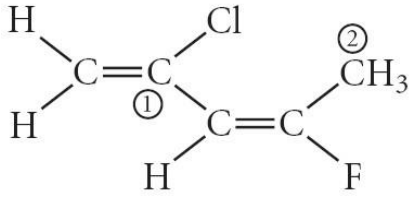
11. What is the strongest type of intermolecular force present in NH_2CH_3?

    A. dispersion
    B. dipole-dipole
    C. hydrogen bonding
    D. ion-dipole
    E. none of the above

12. Identify the polyprotic acid.

    A. H_2SO_4 B. HCl C. LiI D. NaOH E. $Ba(OH)_2$

13. Consider the molecule below. Determine the molecular geometry at each of the two labeled carbons.



    A. C1 = tetrahedral, C2 = linear
    B. C1 = trigonal planar, C2 = bent
    C. C1 = bent, C2 = trigonal planar
    D. C1 = trigonal pyramidal, C2 = see-saw
    E. C1 = trigonal planar, C2 = tetrahedral

14. To what temperature must a balloon, initially at 25 °C and 2.00 L, be heated in order to have a volume of 6.00 L?

A. 993 K B. 403 K C. 75 K D. 655 K E. 894 K

15. The empirical formula of a compound of uranium and fluorine that is composed of 67.6% uranium and 32.4% fluorine is

A. U_2F B. U_3F_4 C. UF_4 D. UF_6 E. UF_8

16. One angstrom, symbolized Å, is 10^{-10} m. 1 cm^3 = _____ $Å^3$.

A. 10^{24} B. 10^{-24} C. 10^{30} D. 10^{-30} E. 10^{-9}

17. A common English set of units for expressing speed is miles/hour. The SI unit for speed is _____.

A. km/hr B. km/s C. m/hr D. cm/s E. m/s

18. An *anion* is defined as

A. a charged atom or group of atoms with a net negative charge.
B. a stable atom.
C. a group of stable atoms.
D. an atom or group of atoms with a net positive charge.
E. another form of a molecule.

19. Give the number of protons (p^+), electrons (e^-), and neutrons (n^o) in one atom of chlorine-37.

A. 37 p^+, 37 e^-, 17 n^o
B. 17 p^+, 17 e^-, 37 n^o
C. 37 p^+, 17 e^-, 20 n^o
D. 17 p^+, 37 e^-, 17 n^o
E. 17 p^+, 17 e^-, 20 n^o

20. The mass % of H in methane (CH_4) is _____.

A. 7.743
B. 4.032
C. 74.87
D. 92.26
E. 25.17

21. Atoms of the same element with different mass numbers are called

A. ions B. neutrons C. allotropes D. isotopes E. chemical families

22. _____ is the abbreviation for the prefix mega-.

A. k B. m C. M D. n E. d

23. Of the following solutions, which has the greatest buffering capacity?

A. 0.821 M HF and 0.217 M NaF
B. 0.821 M HF and 0.909 M NaF
C. 0.100 M HF and 0.217 M NaF
D. 0.121 M HF and 0.667 M NaF
E. They are all buffer solutions and would all have the same capacity.

24. Which one of the following statements is false when considering the rate law below?

$$\text{rate} = k\,[A][B]^2$$

A. The reaction is first order in A.
B. The reaction is second order in B.
C. The reaction is second order overall.
D. *k* is the reaction rate constant.
E. If [B] is doubled, the reaction rate will increase by a factor of 4.

25. What is the wavelength of radiation that has a frequency of $6.912 \times 10^{14}\ s^{-1}$?

A. 1.447×10^{-15} nm
B. 4.337×10^{2} nm
C. 2.304×10^{6} nm
D. 2.074×10^{23} nm
E. 4.337×10^{-7} nm

26. Which one of the following types of elements is most likely to be a good oxidizing agent?

A. alkali metals
B. lanthanides
C. alkaline earth elements
D. halogens
E. transition elements

27. What is the oxidation number of nitrogen in HNO_3?

A. –1 B. +1 C. +3 D. +5 E. +7

28. What period 3 element has the following ionization energies (all in kJ/mol)?

$IE_1 = 1012$ $IE_2 = 1900$ $IE_3 = 2910$ $IE_4 = 4960$ $IE_5 = 6270$ $IE_6 = 22{,}200$

A. P B. S C. Cl D. Mg E. Si

29. How many moles of nitrogen are formed when 58.6 g of KNO_3 decomposes according to the following reaction? The molar mass of KNO_3 is 101.11 g/mol.

$$4\ KNO_3\ (s) \rightarrow 2\ K_2O\ (s) + 2\ N_2\ (g) + 5\ O_2\ (g)$$

A. 1.73 mol
B. 0.290 mol
C. 0.724 mol
D. 18.5 mol
E. 0.580 mol

30. What is the percent yield of C_2H_2 if 62.80 g of water yields 15.38 g of C_2H_2 using the following balanced equation?

$$CaC_2\ (s) + 2\ H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) + C_2H_2\ (g)$$

A. 13.84 %
B. 48.10 %
C. 91.47 %
D. 33.90 %
E. 68.52 %

31. How many C_2H_4 molecules are contained in 45.8 mg of C_2H_4?

A. 2.71×10^{20}
B. 4.69×10^{2}
C. 9.83×10^{20}
D. 3.69×10^{23}
E. 7.74×10^{26}

32. A solution is prepared by dissolving 49.3 g KBr in enough water to form 473 mL of solution. Calculate the mass % of KBr in the solution if the density is 1.12 g/mL.

A. 10.4 %
B. 9.31 %
C. 10.1 %
D. 8.57 %
E. 11.7 %

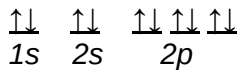
33. Place the following in order of increasing radius. Br^- Na^+ Rb^+

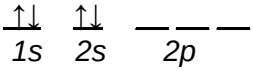
A. $Br^- < Rb^+ < Na^+$
B. $Na^+ < Rb^+ < Br^-$
C. $Rb^+ < Na^+ < Br^-$
D. $Br^- < Na^+ < Rb^+$
E. $Rb^+ < Br^- < Na^+$

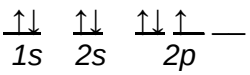
34. Which is the correct ground state electron configuration for Ti^{2+}

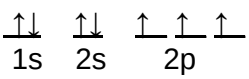
A. $[Ar]4s^23d^4$ B. $[Ar]3d^4$ C. $[Ar]3d^2$ D. $[Ar]4s^2$ E. $[Ar]4s^23d^2$

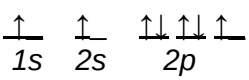
35. Choose the orbital diagram that represents the ground state of N.

A. 

B. 

C. 

D. 

E. 

36. Place the following types of electromagnetic radiation in order of increasing frequency.

x-rays infrared light gamma rays

A. gamma rays < infrared < x-rays
B. x-rays < gamma rays < infrared light
C. gamma rays < x-rays < infrared light
D. infrared light < gamma rays < x-rays
E. infrared light < x-rays < gamma rays

37. How many grams of CCl_4 are needed to make a 1.20 *m* solution in 450 g octane?

A. 62.22 g
B. 127.4 g
C. 83.06 g
D. 184.6 g
E. 221.5 g

38. Calculate the energy of the green light emitted, per photon, by a mercury lamp with a frequency of 5.49×10^{14} Hz.

A. 2.75×10^{-19} J
B. 1.83×10^{-19} J
C. 5.46×10^{-19} J
D. 3.64×10^{-19} J
E. 4.68×10^{-19} J

39. The boiling point elevation of an aqueous sucrose solution is found to be 0.39 ^{o}C. What mass of sucrose (molar mass = 342.30 g/mol) would be needed to dissolve in 500.0 g of water? (k_b = 0.512 ^{o}C/m)

A. 130 g
B. 261 g
C. 223 g
D. 762 g
E. 528 g

40. The equilibrium constant is given for one of the reactions below. Determine the value of the missing equilibrium constant.

$H_2(g) + Br_2(g) \leftrightarrow 2\ HBr(g)$ $\quad K_c = 3.8 \times 10^4$
$2\ HBr(g) \leftrightarrow H_2(g) + Br_2(g)$ $\quad K_c = ?$

A. 5.3×10^{-5} B. 6.4×10^{-4} C. 1.6×10^{3} D. 2.6×10^{-5} E. 1.9×10^{4}