2017 Academic Challenge

CHEMISTRY TEST – STATE

– This Test Consists of 40 Questions –

Chemistry Test Production Team
Iffat Ali, Lake Land College – Author/Team Leader
Mary Konkle, Eastern Illinois University – Author
Gregory Capitosti, Lake Land College – Reviewer
Sahid L. Rosado Lausell, WYSE – Coordinator of Test Production

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 *****

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.

WYSE – Academic Challenge
Chemistry Test (State) – 2017

1. In which of the following sequences of chemical formulas do all members of the sequence fit the description “heteroatomic and triatomic”?

   A. HCN, H_2O and O_3
   B. SO_4^{2-}, NO_3^-, and SO_2
   C. S_2O, SO_2, and SO_3
   D. CO_2, NO_2 and N_2O
   E. no correct response

2. Dissolving is **not** likely to occur to a large extent when

   A. solute-solvent attractions are significantly weak compared to other forces.
   B. solute-solute attractions are weak compared to other forces.
   C. solvent-solvent attractions are weak compared to other forces.
   D. solute-solvent attractions are strong compared to other forces
   E. all interactions are of comparable strength.

3. The freezing point of pure camphor is 178.4 °C, and its molal freezing-point depression constant, K_f, is 40.0 °C/*m*. What is the freezing point of a solution containing 3.00 g of a compound of molar mass 125 g/mol in 45.0 g of camphor?

   A. 174.1 °C B. 11.6 °C C. 135.2 °C D. 140.4 °C E. 157.1 °C

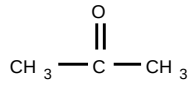
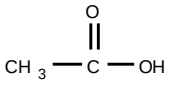
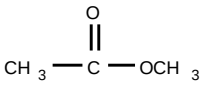
4. When the solubility of compound Y is plotted against temperature, a straight line with a negative slope is obtained. This means that

   A. the solubility of Y increases with increasing temperature.
   B. the solubility of Y decreases with increasing temperature.
   C. the solubility of Y decreases with decreasing temperature.
   D. the solubility of Y is independent of temperature.
   E. all of the above.

5. The mass of a metal cylinder was determined on an analytical balance to be 50.208 g. The volume of the cylinder was determined to be 5.6 mL. The density of the metal cylinder, expressed to the proper number of significant figures, is

   A. 8.9657 g/mL
   B. 0.11153 g/mL
   C. 9.0 g/mL
   D. 0.11 g/mL
   E. 3.50 g/mL

6. Which of the following is the formula for an ether?

		CH_3-CH_2-OH		CH_3–O–CH_3
A.	B.	C.	D.	E.

7. In which of the following choices are the chemical species ordered correctly from smallest radius to largest radius?

   A. B < C < N
   B. Ar < Xe < Kr
   C. Na < Na^+ < K
   D. Cl < S < S^{2-}
   E. K^+ < Ca^{2+} < K

8. Consider the equilibrium reaction:

   $3\ ClO^-(aq) \rightleftharpoons ClO_3^-(aq) + 2\ Cl^-(aq)$ $\qquad K_c = 3.2 \times 10^3$

   The following concentrations are present at certain time:

   $[Cl^-] = 0.50$ mol/L; $[ClO_3^-] = 0.32$ mol/L; $[ClO^-] = 0.24$ mol/L.

   Is the mixture at equilibrium and, if not, in which direction will reaction proceed?

   A. The system is at equilibrium.
   B. The system is not at equilibrium; reaction will proceed from left to right.
   C. The system is not at equilibrium; reaction will proceed from right to left.
   D. The system cannot reach equilibrium since the ClO_3^- and Cl^- concentrations are not in the stoichiometric ratio.
   E. Not enough information is given to make the decision.

9. The formulas of ammonium sulfide and calcium sulfate are

   A. NH_4SO_3, CaS
   B. NH_4S, $CaSO_4$
   C. $(NH_3)_2SO_3$, $CaSO_4$
   D. $(NH_4)_2S$, $CaSO_4$
   E. $(NH_4)_2SO_3$, CaS

10. For the overall hypothetical reaction A + 5 B → 4 C, the rate of appearance of C given by Δ[C]/Δt is the same as

    A. Δ[A]/Δt
    B. $-\frac{\mathbf{5}}{\mathbf{4}}$ (Δ[B]/Δt)
    C. $-\frac{4}{5}$ (Δ[B]/Δt)
    D. $-\frac{\mathbf{1}}{\mathbf{4}}$ (Δ[A]/Δt)
    E. none of the above.

11. Which of the following pairs (specified in terms of subatomic particle composition) represents the isotopes of an atom?

    A. (24 p^+, 24 e^-, 24 nº) and (25 p^+, 24 e^-, 28 nº)
    B. (24 p^+, 24 e^-, 28 nº) and (24 p^+, 21 e^-, 27 nº)
    C. (24 p^+, 24 e^-, 24 nº) and (25 p^+, 25 e^-, 25 nº)
    D. all are correct responses
    E. none is a correct response

12. What is the molar solubility of Ag_2CrO_4 in water? (K_{sp} of Ag_2CrO_4 is 8.0×10^{-12}).

    A. 8.0×10^{-12} *M*
    B. 2.0×10^{-12} *M*
    C. $\sqrt{4.0\text{x}10^{-12}}$ *M*
    D. $\sqrt[3]{4.0 \text{ x } 10^{-12}}$ *M*
    E. $\sqrt[3]{2.0 \text{ x } 10^{-12}}$ *M*

13. On a mountaintop, it is observed that water boils at 90 ºC, not at 100 ºC as it does at the sea level. This phenomenon occurs because on the mountaintop the

    A. equilibrium water vapor pressure is higher due to the higher atmospheric pressure
    B. equilibrium water vapor pressure is lower due to the higher atmospheric pressure
    C. equilibrium water vapor pressure equals the atmospheric pressure at a lower temperature
    D. water molecules have a higher average kinetic energy due to the lower atmospheric pressure
    E. water contains a greater concentration of dissolved gases

14. The density of table sugar is 1.59 g/mL. It is true that

    A. 2.00 g of table sugar occupies a volume of 1.17 mL.
    B. 5.00 g of table sugar occupies a volume of 3.14 mL.
    C. 3.00 g of table sugar occupies a volume of 1.97 mL.
    D. more than one correct response.
    E. no correct response.

15. Which one of the following elements will react with water to form a strong base?

    A. lithium B. nickel C. bromine C. uranium E. fluorine

16. When strongly heated, solid sodium hydrogen carbonate decomposes to form solid sodium carbonate, water vapor, and carbon dioxide gas. What is the equilibrium constant expression (K_c) for this reversible reaction?

    A. $K_c = [H_2O][CO_2]$

    B. $K_c = \frac{[Na_2CO_3][H_2O][CO_2]}{[NaHCO_3]}$

    C. $K_c = [H_2O][CO_2]^2$

    D. $K_c = [CO_2]$

    E. $K_c = \frac{[Na_2CO_3][H_2O][CO_2]^2}{[NaHCO_3]^2}$

17. Choose the appropriate number of atoms contained in a formula unit of calcium chloride.

    A. three atoms per formula unit
    B. four atoms per formula unit
    C. two atoms per formula unit
    D. five atoms per formula unit
    E. six atoms per formula unit

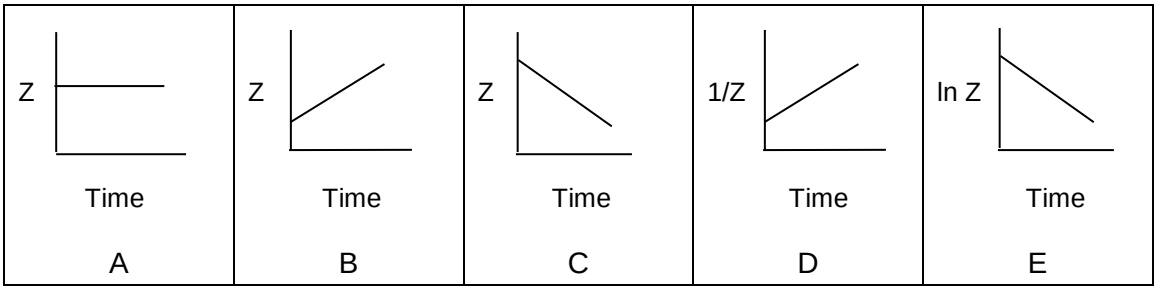
18. After 195 days, a 10.0 g sample of pure ^{95}Zr has decayed to the extent that only 1.25 g of the original ^{95}Zr remains. What is the half-life of this isotope?

    A. 195 days
    B. 97.5 days
    C. 65.0 days
    D. 48.8 days
    E. 24.4 days

19. Which of the following statements is true for a neutron?

    A. It contributes 25% of the mass of an atom.
    B. Its mass is less than that of an electron.
    C. It has a negative charge.
    D. Its mass is about the same as that of a proton.
    E. It contributes 75% of the mass of an atom.

20. A pure substance Z decomposes into two products, X and Y, as shown by the chemical equation. Which of the following graphs of the concentration of Z versus time is consistent with the rate of the reaction being first order with respect to Z? $Z \longrightarrow X + Y$



21. The Arrhenius definition of an acid is

    A. an acid is a proton donor
    B. an acid is a proton acceptor
    C. amphiprotic
    D. a substance, that when dissolved in water, produces OH^- ions
    E. a substance, that when dissolved in water, produces H_3O^+ ions

22. A 25-mL sample of 0.40 *M* HCl is added to 32 mL of 0.30 *M* NaOH. Is the resulting solution acidic, basic, or neutral?

    A. acidic
    B. neutral
    C. basic
    D. all of the above
    E. cannot be determined

23. What is the density (in g/L) of a gas with a molar mass of 60.0 g/mol at 0.750 atm and 27.0 °C?

    A. 1.83 g/L B. 18.3 g/L C. 20.3 g/L D. 2.03 g/L E. cannot be determined

24. Without doing any calculations, identify which of the following lists the compounds in order of increasing entropy.

    A. $H_2O(l) < NaCl(s) < NH_3(g)$
    B. $H_2O(l) < NH_3(g) < NaCl(s)$
    C. $NaCl(s) < H_2O(l) < NH_3(g)$
    D. $NH_3(g) < H_2O(l) < NaCl(s)$
    E. $NH_3(g) < NaCl(s) < H_2O(l)$

25. What is the difference between an alpha particle and a He atom?

    A. nothing, they are the same thing
    B. an alpha particle is a He atom without electrons
    C. an alpha particle is a He atom without protons
    D. an alpha particle is a He atom without neutrons
    E. none of the above

26. Calculate the empirical formula of a compound that is 87.42% of N and 12.58% of H in percent composition.

    A. NH_3 B. NH_4 C. NH_2 D. N_2H_2 E. none of these

27. Which choice below represents a possible set of quantum numbers for one of the valence electrons of calcium?

    A. $n = 4, l = 0, m_l = 0, m_s = +½$
    B. $n = 5, l = 0, m_l = 0, m_s = +½$
    C. $n = 4, l = 4, m_l = 0, m_s = +½$
    D. $n = 4, l = 0, m_l = 0, m_s = 0$
    E. $n = 3, l = 0, m_l = 0, m_s = +½$

28. Select the correct net ionic equation for the reaction of Zn metal and VO_2^+ in acid solution.

A. $Zn + VO_2^+ \rightarrow Zn^{2+} + VO$
B. $Zn + 2\ VO_2^+ \rightarrow Zn^{2+} + 2\ VO$
C. $Zn + 4\ H^+ + VO_2^+ \rightarrow Zn^{2+} + VO + 2\ H_2O$
D. $Zn + 4\ H^+ + 2\ VO_2^+ \rightarrow Zn^{2+} + 2\ VO^{2+} + 2\ H_2O$
E. $Zn + 4\ H^+ + 2\ VO_2^+ \rightarrow Zn^{2+} + 2\ VO^{2+}$

29. Give the molecular geometry for the ion ClO_2^-.

A. tetrahedral
B. trigonal bipyramidal
C. linear
D. octahedral
E. bent

30. Which of the following explains why the boiling points of hydrocarbons (made of only carbon and hydrogen atoms) increase with increasing molar mass?

I. The larger mass makes molecules move slower
II. Hydrogen bond strength increases
III. London forces become more pronounced with a greater number of atoms.

A. I only B. II only C. III only D. I and III E. I, II, and III

31. The hydrogen phosphate ion is amphiprotic. Identify the product formed from this ion when it is reacted with base.

A. H_3PO_4 B. $H_2PO_4^-$ C. HPO_4^{2-} D. PO_4^{3-} E. none of these

32. The following chemical equation is an example of a _____ reaction.

$2\ AgNO_3(aq) + Zn(s) \rightarrow 2\ Ag(s) + Zn(NO_3)_2(aq)$

A. combination
B. decomposition
C. combustion
D. metathesis
E. displacement

33. If a gas occupies 100. mL at 150 kPa, what is its volume at 200. kPa?

A. 75.0 L
B. 0.0750 L
C. 0.0750 mL
D. 750. mL
E. 0.133 L

34. When $\Delta G = 0$, a reaction is

A. spontaneous to the right as the equation is written
B. does not occur
C. at equilibrium
D. not spontaneous to the right; spontaneous to the left
E. instant

35. Calculate the mass percent of carbon in glucose, $C_6H_{12}O_6$.

A. 40.0% B. 20.0% C. 50.0% D. 33.3% E. 35.5%

36. What element/ion has the electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6$ and has 17 protons?

A. argon
B. chloride ion
C. krypton
D. bromide ion
E. sulfide ion

37. Give the balanced chemical equation resulting from the two equations below.

Eqn-1: $Sn(s) \rightarrow Sn^{2+}(aq) + 2\ e^-$

Eqn-2: $Ag^+(aq) + e^- \rightarrow Ag(s)$

A. $Sn(s) + 2\ Ag^+(aq) \rightarrow Sn^{2+}(aq) + 2\ Ag(s) + 2\ e^-$
B. $Sn(s) + 2\ Ag^+(aq) \rightarrow Sn^{2+}(aq) + 2\ Ag(s) + e^-$
C. $Sn(s) + 2\ Ag^+(aq) \rightarrow Sn^{2+}(aq) + Ag(s)$
D. $Sn(s) + Ag^+(aq) \rightarrow Sn^{2+}(aq) + Ag(s)$
E. $Sn(s) + 2\ Ag^+(aq) \rightarrow Sn^{2+}(aq) + 2\ Ag(s)$

38. A polar covalent bond forms when

    A. the shared pair of protons is shared equally
    B. two polar atoms combine
    C. two ions bond
    D. the shared pair of electrons is shared unequally
    E. an electron is transferred from one atom to another

39. Which of the following intermolecular forces is responsible for the attraction between an ion and a polar molecule?

    A. dipole-dipole interaction
    B. hydrogen bonding
    C. ion-dipole interaction
    D. dipole-induced dipole interaction
    E. they would not interact

40. Using the following equation, if you react 15.0 mL of 300 m*M* aluminum phosphate solution with 180 mg of magnesium metal, how many moles of aluminum metal will you produce?

    $2\ AlPO_4(aq) + 3\ Mg(s) \rightarrow 2\ Al(s) + Mg_3(PO_4)_2(aq)$

    A. 4.50 moles
    B. 4.50 millimoles
    C. 4.94 moles
    D. 5.05 millimoles
    E. 4.94 millimoles