2016 Academic Challenge

CHEMISTRY TEST – SECTIONAL

– This Test Consists of 40 Questions –

Chemistry Test Production Team
Iffat Ali, Lake Land College – Author/Team Leader
Kraig A. Wheeler, Eastern Illinois University – Author
Nancy Carter Dopke, Alma 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 (Sectional) – 2016

1. A 30.0 mL sample of H_3PO_4 with unknown concentration is titrated with a 0.100 M NaOH solution. The equivalence point is reached when 26.4 mL of NaOH solution is added. What is the concentration of the unknown H_3PO_4 solution? Following is the neutralization reaction.

$$H_3PO_4(aq) + 3\ NaOH(aq) \rightarrow 3\ H_2O(l) + Na_3PO_4(aq)$$

A. 0.150 M B. 0.0879 M C. 0.0583 M D. 0.0293 M E. 0.0453 M

2. A solution of an acid is mixed with a solution of a base using stoichiometric amounts. The neutral mixture that results contains magnesium nitrate ($Mg(NO_3)_2$). This mixture could have resulted from the combination of which of these pairs of solutions?

A. a solution of MgO and a solution of NH_3
B. a solution of $Mg(OH)_2$ and a solution of NH_3
C. a solution of MgO and a solution of HNO_2
D. a solution of $Mg(OH)_2$ and a solution of HNO_3
E. a solution of $Mg(OH)_2$ and a solution of HNO_2

3. A sample of a certain gas has a volume of 415 mL at 725 mm Hg and 0.00 °C. What would be the volume of this same sample of gas if it were measured at 760 mm Hg and 0.00 °C?

A. 301 mL B. 581 mL C. 830. mL D. 435 mL E. 396 mL

4. Which of the following is **true** regarding the heat of the system and the heat of the surroundings according to thermodynamics?

A. The heat gained by the system is equal to the heat gained by the surroundings.
B. The heat released by the system is equal to the heat gained by the surroundings.
C. The heat lost by the system is less than the heat lost by the surroundings.
D. There is no rule for the heat exchange between the system and the surroundings.
E. Heat gained by the system is greater than the heat gained by the surroundings.

5. What is the half-life of a radioactive nuclide?

A. The period of time it takes to reduce radioactivity by 100%.
B. The time at which the isotope becomes non-radioactive.
C. The period of time in which 25% of the original number of atoms undergoes radioactive decay.
D. The period of time in which the daughter nuclide's atomic mass becomes half of the original element.
E. The period of time in which 50% of the original number of atoms undergo radioactive decay.

6. Nicotine contains 74.03% C, 8.70% H, and 17.27% N. What is its empirical formula?

A. C_5H_7N B. C_5HN_2 C. C_4H_7N D. $C_4H_5N_2$ E. $C_{10}H_{14}N_2$

7. Determine the wavelength of light with energy of 2.25×10^{-19} J.

A. 1.13×10^{6} m
B. 8.83×10^{-7} m
C. 1.02×10^{23} m
D. 4.98×10^{-61} m
E. 1.13×10^{-6} m

8. Following is a list of reduction potentials of a number of ions. Based on the given values, predict which of the following metals will be the easiest to oxidize.

$Au^{3+}(aq) + 3\ e^- \rightarrow Au(s)$ $E^o = 1.50$ V
$Ni^{2+}(aq) + 2\ e^- \rightarrow Ni(s)$ $E^o = -0.25$ V
$Pd^{2+}(aq) + 2\ e^- \rightarrow Pd(s)$ $E^o = 0.987$ V
$Sn^{2+}(aq) + 2\ e^- \rightarrow Sn(s)$ $E^o = -0.14$ V
$Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$ $E^o = -0.763$ V

A. Au B. Ni C. Pd D. Sn E. Zn

9. The molecule 1-propene has the structure $H_3C{-}CH{=}CH_2$ where the symbols "–" and "═" signify a single and double bond, respectively. How many of the carbon atoms in this molecule are sp^2 hybridized?

A. 0 B. 1 C. 2 D. 3 E. 4

10. What might the reason be for the boiling point of H_2O being so much higher than that of H_2S?

A. Water does hydrogen bonding and hydrogen sulfide does not.
B. Water has lighter molar mass than that of hydrogen sulfide.
C. Oxygen uses 2s orbital for bonding and sulfur uses 3p orbitals for that purpose.
D. The two examples use different hybridization schemes.
E. None of these answers are correct.

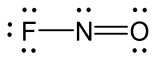
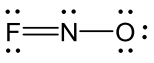
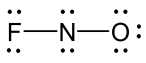
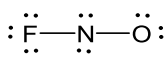
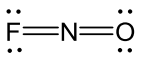
11. The vapor pressure of pure hexane (C_6H_{14}) is 100. torr at 15.8 °C. Calculate the vapor pressure of a solution containing 20.0 g of naphthalene ($C_{10}H_8$) dissolved in 50.0 mL hexane. The density of hexane is 0.877 g/mL.

A. 87.7 torr B. 86.5 torr C. 32.6 torr D. 105. torr E. 76.5 torr

12. What mass of solute is present in 340. mL of a 5.50 M solution of KOH?

A. 105 g B. 1.05 g C. 1.87 g D. 74.8 g E. 56.1 g

13. Which of the following Lewis structures best represents the bonding in NOF based on minimizing the formal atomic charges?

A.  B.  C.  D.  E. 

14. Exposing a certain substance to an electric field produces carbon and chlorine. This substance cannot be:

A. a compound
B. an element
C. a mixture
D. a pure substance
E. any of the above answers

15. Acetanilide has a solubility of 5.5 g/100. mL in 100 °C water. An amount of 3.5 g of acetanilide was added to 42.0 mL of 100 °C water and the undissolved acetanilide collected. What is the percent recovery of the collected acetanilide?

A. 2.3 g B. 34% C. 34.3 % D. 64 % E. 64.2 %

16. Which of the following has the highest boiling point?

A. F_2 B. Cl_2 C. Br_2 D. I_2 E. Ar

17. An indication that a system at equilibrium favors the products is a _____.

A. large K_{eq}
B. positive ΔH
C. one step mechanism
D. low activation energy
E. equal forward and reverse rates of reaction

18. The correct name for N_2O_5 is

A. nitrogen pentoxide
B. pentaoxygen dinitride
C. dinitrogen tetroxide
D. dinitrogen pentoxide
E. nitrous oxide

19. For irreversible chemical reactions, the rate will be affected by changes in all of these factors except:

A. concentration of reactants
B. concentration of products
C. presence of catalyst
D. surface area of solid reactants
E. temperature

20. Identify the acid, base, conjugate acid, and conjugate base in the following reaction.

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

Acid : Base	Conj. base : Conj. acid
A. $NH_3 : H_2O$:	$OH^- : NH_4^+$
B. $NH_4^+ : OH^-$	$NH_3 : H_2O$
C. none : NH_3	OH^- : none
D. none : H_2O	NH_4^+ : none
E. $H_2O : NH_3$	$OH^- : NH_4^+$

21. A 52.6 mL of 0.724 M solution of potassium hydroxide solution is titrated with a 0.439 M solution of a nitric acid solution. What is the expected volume of nitric acid at the equivalence point according to the following reaction?

$$KOH\ (aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$$

A. 52.6 mL B. 86.7 mL C. 43.4 mL D. 21.7 mL E. 72.4 mL

22. Which of the following gases would have the greatest density at a given temperature (consider pressure and volume to be constant)?

A. CO_2 B. H_2 C. NH_3 D. CO E. Ne

23. Five metal spoons are dipped in a bowl of hot soup. Use the specific heat capacities (c_p) given in parenthesis to identify the spoon that will heat up faster for a given mass.

A. Aluminum (0.897 J/g.K)
B. Copper (0.385 J/g.K)
C. Silver (0.235 J/g.K)
D. Gold (0.129 J/g.K)
E. Nickel (0.445 J/g.K)

24. What is the percentage of oxygen in caffeine, $C_8H_{10}N_4O_2$?

A. 49.5% B. 28.9% C. 16.5% D. 32.7% E. 8.33%

25. Which of the following represents the ground state electron configuration of a neutral calcium atom?

A. $1s^2\,2s^2\,2p^6\,3s^2\,3p^5$
B. $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$
C. $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2$
D. $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^3$
E. $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^2$

26. What is the balanced net ionic equation for the reaction of aluminum sulfate with sodium hydroxide?

A. $2\ Na^+(aq) + SO_4^{2-}(aq) \rightarrow Na_2SO_4(s)$
B. $Al_2(SO_4)_3(aq) + 6\ NaOH(aq) \rightarrow 2\ Al(OH)_3(aq) + 3\ Na_2SO_4(s)$
C. $Al^{3+}(aq) + 3\ OH^-(aq) \rightarrow Al(OH)_3(s)$
D. $Al_2(SO_4)_3(aq) + 6\ NaOH(aq) \rightarrow 2\ Al(OH)_3(s) + 3\ Na_2SO_4(s)$
E. $3\ Al(s) + 3\ OH^-(aq) \rightarrow Al(OH)_3(s)$

27. Which of the following combinations of two elements is most likely to produce highly ionic bonds?

A. nitrogen and oxygen
B. nitrogen and fluorine
C. boron and nitrogen
D. lithium and fluorine
E. hydrogen and fluorine

28. Iodine and frozen carbon dioxide pass directly from the solid phase to the gas phase (skipping the liquid phase) if heat is applied. What is this phase transformation from solid to gas called?

A. sublimation B. deposition C. freezing D. boiling E. condensation

29. Which of the following statements about atomic structure is **incorrect**?

A. Protons and neutrons in the nucleus are tightly packed.
B. Most of the mass of an atom is concentrated in the nucleus.
C. Electrons are located in quantized energy levels.
D. The number of protons and neutrons are always equal.
E. The space occupied by electrons is larger than the volume of the nucleus.

30. Which ion(s) participates as a spectator ion(s) in the precipitation of $MgSO_3$ from combining aqueous solutions of Na_2SO_3 and $MgCl_2$?

A. Na^+ only B. Mg^{2+} only C. Na^+ and Cl^- D. SO_3^{2-} and Cl^- E. Mg^{2+} and SO_3^{2-}

31. Two students, Lisa and Mark, determined the mass of an object. Lisa measured the object and received the values of 1.135 mg, 1.131 mg, 1.138 mg, and 1.137 mg. Mark measured the same object and received 0.913 mg, 0.811 mg, 0.990 mg, and 0.798 mg. The accepted mass of the object is 0.825 mg. Which statement(s) best describes the results obtained by Lisa and Mark.

A. Lisa's results were more precise.
B. Lisa's results were more accurate.
C. Mark's results were more accurate.
D. Lisa and Mark's results were equally precise.
E. Answers A and C.

32. Which statement about noble gases is correct?

A. They form highly colored compounds.
B. They are highly reactive with halogens and metals.
C. Their abundance in nature is low.
D. Readily form ions.
E. They exist as single atoms rather than as molecules.

33. Consider the following equilibrium:

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$$

At equilibrium, the $[H_2] = 0.015$ mol/L, $[I_2] = 0.015$ mol/L and $[HI] = 0.23$ mol/L. What is the value of the equilibrium constant?

A. 4.3×10^{-3} B. 1.6×10^{-2} C. 2.3×10^{2} D. 1.5×10^{2} E. 1.0×10^{-1}

34. What is the correct formula for cesium sulfate?

A. $CsSO_4$ B. Cs_2SO_3 C. Cs_2SO_4 D. Cs_2SO_5 E. Se_2SO_4

35. If you use 12 mol of H_2 and 7 mol of O_2 to form H_2O, which is the limiting reagent and why?

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

A. O_2, because 7 mol O_2 is lower in number than 12 moles H_2.
B. H_2, because all of H_2 will be used up and some of O_2 will remain as excess.
C. O_2, because you will need additional 5 mol.
D. H_2, because you will have 5 mol left over.
E. O_2, because it is very reactive.

36. The chemical equation for the reaction of nitrogen oxide, NO, and chlorine, Cl_2, is:

$$2\ NO + Cl_2 \rightarrow 2\ NOCl$$

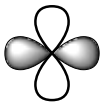
The initial rates of reaction for various concentrations of the reactants were measured and recorded at constant temperature as follows:

Experiment	[NO] (M)	$[Cl_2]$ (M)	$^{-}\Delta[Cl_2]/\Delta t$ (M/hr)
1	0.10	0.30	0.50
2	0.10	0.60	2.01
3	0.20	1.20	16.05

Calculate the numerical value for the rate constant (k) in $L^2/mol^2 \cdot$ hr.

A. 56 B. 17 C. 4.0 D. 8.0 E. 1.0

37. Which sketch represents an orbital with the quantum numbers $n = 4$, $l = 0$, $m_l = 0$?

A.  B.  C.  D.  E. 

38. What is the percent $KClO_4$ by mass in a 2.00 molal aqueous solution?

A. 12.2% B. 13.8% C. 18.5% D. 21.7% E. 54.2%

39. Which set of quantum numbers is **not** allowed?

A. $n = 4, l = 2, m_l = 2, s = +½$
B. $n = 2, l = 0, m_l = 0, s = +½$
C. $n = 5, l = 4, m_l = –4, s = –½$
D. $n = 3, l = 1, m_l = –1, s = –½$
E. $n = 2, l = 2, m_l = 0, s = +½$

40. Atoms that gain or lose electrons are called

A. non-metals B. ions C. isotopes D. molecules E. metals