2016 Academic Challenge

CHEMISTRY TEST – STATE

– This Test Consists of 40 Questions –

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 *****

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) – 2016

1. Which of the following salts would likely have no effect on the pH of a solution?

A. NaOH B. NaCl C. Na_2S D. CH_3COONa E. $NaHCO_3$

2. A solution of silver nitrate ($AgNO_3$) is added to a solution of sodium hydroxide (NaOH). In the precipitation reaction that occurs, which ions will be spectator ions?

A. Ag^+ and OH^-
B. Na^+ and NO_3^-
C. Na^+ and OH^-
D. OH^- and NO_3^-
E. H^+ and OH^-

3. A 1.92 gram sample of an unknown gas occupies a volume of 673 mL at STP. What is the molar mass of the unknown gas?

A. 63.9 g/mol B. 57.7 g/mol C. 12.0 g/mol D. 351 g/mol E. 200. g/mol

4. Which of the following is **not** a standard enthalpy of formation reaction?

A. $\frac{1}{2}\ N_2\ (g) + 3/2\ H_2(g) \rightarrow NH_3(g)$
B. $CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$
C. $H_2\ (g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l)$
D. $C(graphite) + O_2(g) \rightarrow CO_2(g)$
E. $C(graphite) + \frac{1}{2}\ O_2(g) \rightarrow CO(g)$

5. Alpha radiation is symbolized as $^4_2\mathrm{He}^{2+}$. Identify the correct subatomic particle count of the species.

	Neutron	Proton	Electron
A.	2	2	0
B.	2	2	2
C.	2	4	2
D.	4	2	0
E.	4	2	2

6. Combustion analysis of a hydrocarbon produced 33.010 g CO_2 and 13.511 g H_2O. What is the empirical formula of this hydrocarbon?

A. C_2H_4 B. C_2H_5 C. C_2H_6 D. C_2H_3 E. CH_2

7. Certain light energy used to eject an electron from an atom is 1.96×10^{-17} J. What is the frequency of this light?

A. $3.38 \times 10^{-17}\ s^{-1}$
B. $-3.55 \times 10^{16}\ s^{-1}$
C. $2.96 \times 10^{16}\ s^{-1}$
D. $10.1\ s^{-1}$
E. $3.38 \times 10^{17}\ s^{-1}$

8. Which of the following is **not** a redox reaction?

A. $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
B. $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$
C. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$
D. $C(s) + O_2(g) \rightarrow CO_2(g)$
E. $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$

9. According to VSEPR theory, the number of atoms bonded to the central atom normally expected to produce an octahedral geometry is:

A. three B. four C. five D. six E. eight

10. Which of the following correctly shows the forces holding a substance together in order of strength, with weakest first?

A. London dispersion, dipole-dipole, ion-dipole, ion-ion
B. Ion-ion, ion-dipole, dipole-dipole, London dispersion
C. Dipole-dipole, ion-dipole, London dispersion, ion-ion
D. Ion-ion, London dispersion, dipole-dipole, ion-dipole
E. Dipole-dipole, ion-ion, London dispersion, ion-dipole

11. What is the pH of 5.0×10^2 mL of 0.10 M CH_3COOH? The pK_a of CH_3COOH is 4.76.

A. 1.44 B. 3.56 C. 2.88 D. 2.38 E. 4.76

12. What is the coefficient for oxygen in the properly balanced equation for the combustion of octane and oxygen gas to form carbon dioxide gas and water, according to the equation?

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$$

A. 5 B. 10 C. 15 D. 25 E. 50

13. What are the permissible m_l values for a set of **d** orbitals?

A. 0, 1, 2, 3, 4
B. 1, 2, 3, 4, 5
C. –1, 0, 1
D. –2, –1, 0, 1, 2
E. –3, –2, -1, 0, 1, 2, 3

14. A 5.10 g sample of iron is heated from 36.0 °C to 75.0 °C. The amount of energy required is 89.5 J. What is the specific heat capacity of iron?

A. 1.78×10^4 J/g ·°C
B. 11.7 J/g ·°C
C. 0.900 J/g ·°C
D. 0.230 J/g ·°C
E. 0.450 J/g ·°C

15. Caffeine contains 49.48% C, 5.190% H, 28.85% N, and 16.48% O. What is its empirical formula?

A. $C_8H_{10}N_4O_2$ B. $C_4HN_2O_2$ C. $C_5H_5N_2O$ D. $C_4H_5N_2O$ E. $C_3HN_3O_2$

16. Suppose that you have a 2.0 L sample of hydrogen gas at 1.00 atm and 59 °C. If you heat the gas to 84 °C and it expands to a volume of 3.7 L, what will the final pressure be?

A. 0.58 atm B. 0.76 atm C. 0.25 atm D. 1.0 atm E. 1.5 atm

17. Metallic zinc reacts with aqueous copper(II) ion to produce aqueous zinc(II) ion and copper metal.

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

From the following list, select the line that best describes what happens to some species during the reaction.

A. Species Oxidized: $Cu^{2+}(aq)$ Species Reduced: $Zn^{2+}(aq)$
B. Species Oxidized: $Zn^{2+}(aq)$ Species Reduced: $Cu^{2+}(aq)$
C. Species Oxidized: Zn(s) Species Reduced: Cu(aq)
D. Species Oxidized: $Cu^{2+}(aq)$ Species Reduced: Zn(s)
E. Species Oxidized: Zn(s) Species Reduced: $Cu^{2+}(aq)$

18. Which of the following has only one lone (nonbonding) pair of electrons on the central atom?

A. $AsBr_5$ B. IF_5 C. I_3^- D. XeF_4 E. SF_6

19. The following reaction is which type?

$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$

A. acid base B. precipitation C. redox D. combustion E. combination

20. Which molecule has the strongest and shortest carbon-carbon bond?

A. $H_3C{-}CH{=}O$ B. $H_2C{=}CH_2$ C. $HC{\equiv}CH$ D. $H_3C{-}CH_3$ E. $H_3C{-}CCl_3$

21. How many unhybridized *p*-orbitals are there in a *sp* hybridized nitrogen atom?

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

22. Which of the following occurs when equal volumes of aqueous 0.20 M MgS and 0.20 M $ZnSO_4$ are mixed?

A. Precipitates of $MgSO_4$ and ZnS form.
B. A precipitate of $MgSO_4$ forms.
C. A precipitate of ZnS forms.
D. A precipitate does not form.
E. Precipitates of MgS and $ZnSO_4$ form.

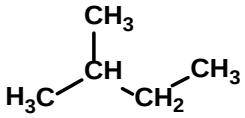
23. Which one of the following statements about the chemical properties of the alkali metals (Group IA) is correct?

A. Lowest ionization energy in a period
B. Highest electron affinity in the period
C. Nonmetallic character
D. Tendency to form a negative charge
E. Smallest atomic radius in a period

24. At 25 °C, the density of water is 0.997 g/mL, whereas the density of ice at –10 °C is 0.920 g/mL. If a 300. mL container is filled with pure water at 25 °C and then frozen at –10 °C, what volume will the solid occupy?

A. 280 mL B. 320 mL C. 275 mL D. 325 mL E. 350 mL

25. What IUPAC name best describes the following molecule?



A. 2-Ethylpropane
B. Pentane
C. 1,1,2-Trimethylethane
D. 2-Methylbutane
E. 1,1-Dimethylpropane

26. Which of the following has the largest radius?

A. F^- B. O^{2-} C. Na^+ D. Mg^{2+} E. Ne

27. Consider the following equilibrium:

$$Cl_2(g) + Br_2(g) \rightleftarrows 2\ ClBr(g)$$

Chlorine gas and bromine gas react when placed in a closed vessel. As the reaction proceeds to equilibrium, the rate of the reverse reaction

A. increases as the concentration of products increases.
B. decreases as the concentration of products decreases.
C. increases as the concentration of products decreases.
D. decreases as the concentration of products increases.
E. increases as the concentration of products stays the same.

28. Which of the following describes all systems in chemical equilibrium?

A. The concentration of reactants and products is equal.
B. The reactants and products are present in the same ratio as the balanced equation.
C. The mass of the reactants equals the mass of the products.
D. The rate of the forward reaction equals the rate of the reverse reaction.
E. The activation energy is the same for the forward and reverse reactions.

29. What is the correct name for $Mn(NO_3)_2$?

A. manganese(III) nitrite
B. magnesium(II) nitrate
C. manganese(II) nitrite
D. manganese(II) nitrate
E. manganic nitrate

30. Under certain conditions, the average rate of appearance of oxygen gas in the reaction:

$$2\ O_3(g) \rightarrow 3\ O_2(g)$$

is 4.0 torr/s. What is the average rate expressed in units torr/s for the disappearance of O_3?

A. 1.2 B. 2.7 C. 4.0 D. 6.0 E. 9.0

31. Which is <u>not</u> a plausible excited state electron configuration for Aluminum ($_{13}Al$)?

A. $1s^2 2s^2 2p^5 3s^2 3p^2$
B. $[Ne]3s^2 3p^1$
C. $1s^2 2s^2 2p^6 3s^2 3p^2$
D. $1s^2 2s^2 2p^6 3s^1 3p^2$
E. Answers B and C

32. What volume of a 0.500 M of an aqueous solution of $FeCl_3$ is needed to prepare 250. mL of solution that has a chloride concentration of 0.100 M?

A. 12.5 mL B. 50.0 mL C. 25.0 mL D. 16.7 mL E. 100. mL

33. What mass of ethylene glycol, $HOCH_2CH_2OH$, must be added to 3.60 kg of water to lower the freezing point of the water from –5.00 °C to –23.0 °C? (K_{fp} for water is –1.86 °C/*m*)

A. 64.8 g B. 121 g C. 1250 g D. 1620 g E. 2170 g

34. Aluminum carbide (Al_4C_3) reacts with water to produce methane (CH_4). If 7.85 g of methane were produced in 40.1% yield, how much aluminum carbide did the reaction start with?

$$Al_4C_3(s) + 12\ H_2O(l) \rightarrow 4\ Al(OH)_3(s) + 3\ CH_4\ (g)$$

A. 58.6 g B. 27.4 g C. 70.4 g D. 175 g E. 221 g

35. Which of the following chemists proposed the period law stating “the physical and chemical properties of elements are a periodic function of their atomic weights?”

A. Davy B. Moseley C. Lavoisier D. Brand E. Mendeleev

36. A mixture consisting of 2.00 moles of PCl_5, 1.50 moles of Cl_2, and 4.00 moles of PCl_3 in a 5.00 L vessel were allowed to reach equilibrium. At equilibrium, the concentration of Cl_2 was found to be 0.180 M. Determine the value of the equilibrium constant (K_{eq}) for the reaction:

$$PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$$

A. 2.35×10^{-1} B. 3.30×10^{1} C. 1.67 D. 4.25 E. 2.03×10^{-5}

37. The rates of chemical reactions increase with temperature because as the temperature increases:

A. The activation energy decreases.
B. The rate constant increases.
C. The equilibrium constant increases.
D. The concentration of reactants and products increase.
E. The activation energy increases.

38. Which of the following are incorrectly paired?

A. Ne, noble gas
B. Fr, lanthanide
C. I, halogen
D. Sn, metal
E. Ca, alkaline earth metal

39. Arrange the following aqueous solutions in order of increasing vapor pressure at 25 °C: 0.35 *m* $C_2H_4(OH)_2$ (ethylene glycol); 0.50 *m* sugar; 0.20 *m* KBr; and 0.20 *m* Na_2SO_4.

A. $C_2H_4(OH)_2$ < sugar < KBr < Na_2SO_4
B. KBr = Na_2SO_4 < $C_2H_4(OH)_2$ < sugar
C. Na_2SO_4 < sugar< KBr < $C_2H_4(OH)_2$
D. Na_2SO_4 < $C_2H_4(OH)_2$ < KBr < sugar
E. Sugar > $C_2H_4(OH)_2$ < KBr < Na_2SO_4

40. It takes 35.0 seconds for the concentration of a reactant in a first-order reaction to drop from 0.350 to 0.210 M. How long will it take in seconds for the reaction to be 80% complete?

A. 17.5 B. 110 C. 46.7 D. 35.0 E. 154