Worldwide Youth in Science and Engineering

2013 Academic Challenge

CHEMISTRY TEST - SECTIONAL

This Test Consists of 40 Questions

Chemistry Test Production Team
Doug Mulford, Emory University – Author/Team Leader
Tracy Morkin, Emory University – Author
Nancy Carter Dopke, Alma College – Reviewer
Mary Weaver, 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. Only one oval should be marked to answer each question. Multiple ovals will automatically be graded as incorrect answers.

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												3A	4A	5A	6A	7A	8A
1 H 1.008	2A																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

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

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

$\Delta T_b = i K_b \bullet m$

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

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

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

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

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

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

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

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

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

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

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

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

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

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

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

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

$\Delta G° = nF\varepsilon°$

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

$F = 96485$ C/mol

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

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

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

1.0 kg = 2.2 lb

1 atm = 101,325 Pa = 1.01325 bar

1.0 in = 2.54 cm

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

1 lb = 453.59 g

$c = \lambda\nu$

$c = 2.998 \times 10^8$ m/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) – 2013

1. Which of the following contains the greatest number of atoms?

   A. 1 mole of S_8 molecules
   B. 2 moles of P_4 molecules
   C. 4 moles of oxygen molecules
   D. 8 moles of iron metal
   E. all of above contain the same number of atoms

2. A glass of cold milk sometimes forms a coat of water on the outside of the glass (often referred to as 'sweat'). How does most of the water get there?

   A. Water evaporates from the milk and condenses on the outside of the glass.
   B. The glass acts like a semi-permeable membrane and allows the water to pass, but not the milk.
   C. Water vapor condenses from the air.
   D. The coldness causes oxygen and hydrogen from the air to combine on the glass, forming water.
   E. It is impossible to predict.

3. The “lead” used in lead pencils is actually graphite, an elemental (pure) form of carbon. If the period at the end of a sentence weighs, on average, 0.00013 g, how many carbon atoms are present in that period?

   A. 6.5×10^{18} atoms
   B. 7.8×10^{19} atoms
   C. 6.2×10^{20} atoms
   D. 5.6×10^{21} atoms
   E. 9.4×10^{21} atoms

4. Which of the following atoms has the largest second ionization energy (IE_2)?

   A. Mg B. Cl C. S D. Ca E. Na

5. All of the following are in aqueous solution. Which is incorrectly named?

   A. H_2SO_4, sulfuric acid
   B. H_2CO_3, carbonic acid
   C. H_3PO_4, phosphoric acid
   D. HCN, cyanic acid
   E. HCl, hydrochloric acid

6. GeF_3H is formed from GeH_4 and GeF_4 in the combination reaction:

   $$GeH_4 + 3\ GeF_4 \rightarrow 4\ GeF_3H$$

   If the reaction yield is 92.6%, how many moles of GeF_4 are needed to produce 8.00 mol of GeF_3H?

   A. 11.6 mol B. 5.56 mol C. 6.48 mol D. 2.78 mol E. 6.00 mol

7. Which of the following statements is <u>false</u>?

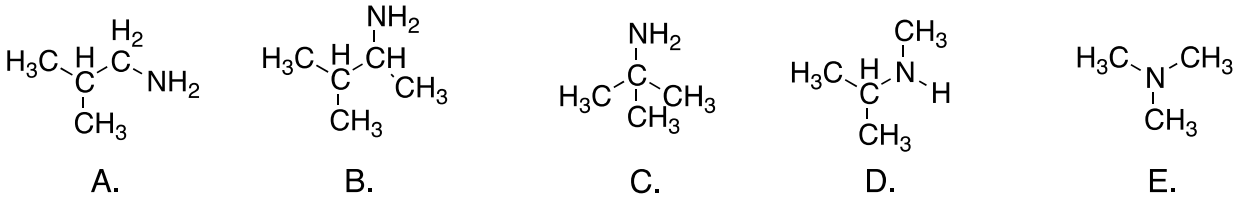
   A. An orbital is a region in space where an electron might be found with 90% probability.
   B. As an electron absorbs more energy, the orbital in which it might be found becomes larger and/or more complex.
   C. For each successive energy level, a new type of orbital is added.
   D. For each orbital, an electron orbits the nucleus around the outer edge according to the shape of the orbital.
   E. The d orbitals begin at the third principle energy level and can hold a maximum of 10 electrons for a given energy level.

8. An element with the following electron configuration is a(n):

   $$[\text{noble gas core}]ns^2(n\text{-}1)d^{10}np^5$$

   A. transition metal
   B. halogen
   C. alkali metal
   D. noble gas
   E. alkaline earth metal

9. Which of the following is a tertiary amine?



   A. B. C. D. E.

10. Which of the series of elements listed below would have most nearly the same atomic radius?

    A. Sc, Ti, V, Cr
    B. Na, K, Rb, Cs
    C. B, Si, As, Te
    D. F, Cl, Br, I
    E. Na, Mg, Al, Si

11. Consider the 4 net ionic equations below. Which of the reactions can be considered Brønsted-Lowry acid-base reactions?

    (I) $Mg_{(s)} + 2H_3O^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)} + 2H_2O_{(l)}$
    (II) $CO_3^{2-}{}_{(aq)} + H_3O^+_{(aq)} \rightarrow HCO_3^-{}_{(aq)} + H_2O_{(l)}$
    (III) $H_3O^+_{(aq)} + OH^-_{(aq)} \rightarrow 2H_2O_{(l)}$
    (IV) $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$

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

12. Tabulated below are initial rate data for the reaction shown. What is the experimentally determined rate law?

$$2Fe(CN)_6^{3-}\ (aq)\ +\ 2I^-\ (aq) \rightarrow 2Fe(CN)_6^{4-}\ (aq)\ +\ I_2\ (aq)$$

Run	$[Fe(CN)_6^{3-}]_0$	$[I^-]_0$	$[Fe(CN)_6^{4-}]_0$	$[I_2]_0$	Initial Rate (M/s)
1	0.01	0.01	0.01	0.01	$1x10^{-5}$
2	0.01	0.02	0.01	0.01	$2x10^{-5}$
3	0.02	0.02	0.01	0.01	$8x10^{-5}$
4	0.02	0.02	0.02	0.01	$8x10^{-5}$
5	0.02	0.02	0.02	0.02	$8x10^{-5}$

A. rate = $k[Fe(CN)_6^{3-}]^2 [I^-]^2 [Fe(CN)_6^{4-}]^2 [I_2]$
B. rate = $k[Fe(CN)_6^{3-}]^2 [I^-] [Fe(CN)_6^{4-}] [I_2]$
C. rate = $k[Fe(CN)_6^{3-}]^2 [I^-]$
D. rate = $k[Fe(CN)_6^{3-}] [I^-]^2$
E. rate = $k[Fe(CN)_6^{3-}] [I^-] [Fe(CN)_6^{4-}]$

13. For a given reaction, $\Delta H° = 40$ kJ and $\Delta S° = 50$ J/K. Which statement is true about the reaction under standard conditions?

A. It is spontaneous at temperatures less than 10 K.
B. It is spontaneous at temperatures greater than 800 K.
C. It is spontaneous only at temperatures between 10 K and 800 K.
D. It is spontaneous at all temperatures.
E. It is non-spontaneous at all temperatures.

14. An automobile gas tank holds 21.1 kg of gasoline. When the gas burns, 84.0 kg of oxygen is consumed and carbon dioxide and water are produced. What is the total combined mass of carbon dioxide and water that is produced?

A. 21.0 kg B. 63.0 kg C. 6.84 kg D. 105 kg E. 135 kg

15. What is the net ionic equation for the reaction that occurs when sodium hydroxide is added to the HCOONa/HCOOH buffer?

A. $NaOH\ (aq) + H_3O^+\ (aq) \rightarrow Na^+\ (aq) + 2\ H_2O\ (l)$
B. $Na^+(aq) + OH^-\ (aq) + H^+\ (aq) \rightarrow Na^+\ (aq) + H_2O\ (l)$
C. $NaOH\ (aq) + HCOOH\ (aq) \rightarrow HCOONa\ (aq) + H_2O\ (l)$
D. $Na^+\ (aq) + HCOOH\ (aq) \rightarrow NaH\ (aq) + HCOO^+\ (aq)$
E. $OH^-\ (aq) + HCOOH\ (aq) \rightarrow HCOO^-\ (aq) + H_2O\ (l)$

16. What is the molecular shape of I_3^-?

A. linear
B. trigonal planar
C. tetrahedral
D. bent
E. none of these

17. Arrange the following aqueous solutions, each 10% by mass in solute, in order of increasing boiling point: glucose ($C_6H_{12}O_6$), sucrose ($C_{12}H_{22}O_{11}$), and raffinose ($C_{18}H_{32}O_{16}$).

    A. glucose, sucrose, raffinose
    B. glucose, raffinose, sucrose
    C. sucrose, raffinose, glucose
    D. raffinose, glucose, sucrose
    E. raffinose, sucrose, glucose

18. The following reaction is at equilibrium in a closed container:

$$3\ Fe(s) + 4\ H_2O(g) \rightleftarrows Fe_3O_4(s) + 4\ H_2(g) \quad (\Delta H° < 0)$$

    Consider the following stresses to the system:

    I. raising the temperature
    II. adding a catalyst
    III. doubling the volume of the container

    Which of these stresses will result in more hydrogen gas being formed?

    A. I and II
    B. II and III
    C. I and III
    D. I, II, and III
    E. None of the above

19. The following reaction is investigated (assume an ideal gas mixture):

$$2\ N_2O(g) + N_2H_4(g) \leftrightarrow 3N_2(g) + 2H_2O(g)$$

    Initially there are 0.10 moles of N_2O and 0.25 moles of N_2H_4, in a 10.0-L container. If there are 0.061 moles of N_2O at equilibrium, how many moles of N_2 are present at equilibrium?

    A. 0.020 moles
    B. 0.039 moles
    C. 0.059 moles
    D. 0.12 moles
    E. 0.09 moles

20. Which of the following groups of gaseous samples contains no ionic compounds?

    A. HCN, NO_2, NH_4Cl
    B. KOH, CCl_4, SF_4
    C. NaH, CaF_2, $NaNH_2$
    D. CH_2O, HCl, NH_3
    E. More than one of A-D contains no ionic compounds.

21. Colligative properties of ideal solutions depend on:

    A. the chemical properties of the solute.
    B. the chemical properties of the solvent.
    C. the number of particles dissolved.
    D. the molar mass of the solute.
    E. The chemical identity of the solute **and** the solvent

22. Safrole is used as a topical antiseptic. Calculate the vapor pressure of a solution prepared by dissolving 0.75 mol of safrole (non-volatile) in 950 g of ethanol (M = 46.07 g/mol). $P°_{ethanol}$ = 50.0 torr at 25°C

A. 1.8 torr B. 11 torr C. 40. torr D. 48 torr E. 55 torr

23. What is the pH of a 1.20 M HCl solution

A. -0.079
B. 0.00
C. 0.079
D. 1.2
E. Cannot be determined

24. What volume of 0.25 M sodium bromide, NaBr, contains 2.0×10^{-4} moles of bromide ions?

A. 0.040 L B. 0.080 L C. 4.0 mL D. 8.0 mL E. 0.80 mL

25. What are the respective concentrations (M) of Na^+ and SO_4^{2-} afforded by dissolving 0.500 mol Na_2SO_4 in water and diluting to 1.33 L?

A. 0.665 M and 0.665 M
B. 0.665 M and 1.33 M
C. 1.33 M and 0.665 M
D. 0.376 M and 0.752 M
E. 0.752 M and 0.376 M

26. Most reactions are more rapid at high temperatures than at low temperatures. This is consistent with which of the following?

(i) An increase in the rate constant with increasing temperature.
(ii) A decrease in the activation energy with increasing temperature.
(iii) An increase in the percentage of high-energy collisions with increasing temperature.

A. (i) only
B. (ii) only
C. (iii) only
D. (i) and (iii)
E. (i), (ii), and (iii)

27. A 9.81-g of solid CO_2 (dry ice) is allowed to sublime in a balloon. The final volume of the balloon is 1.00 L at 299 K. What is the pressure of the gas?

A. 5.47 atm B. 2.41×10^2 atm C. 2.50 atm D. 0.183 atm E. none of these

28. Which of the following molecules is non-polar?

A. CF_4
B. CHF_3
C. CH_2F_2
D. CH_3F
E. More than one of A – D is non-polar.

29. Given a cylinder of fixed volume filled with 1 mol of argon gas, which of the following is correct? Assume ideal behavior in all cases.

    A. If the temperature of the cylinder is changed from 25°C to 50°C, the pressure inside the cylinder will double.
    B. If a second mole of Ar is added, the T/P ratio would remain constant.
    C. A cylinder of identical volume filled with the same pressure of helium must contain more atoms of gas because He has a smaller atomic radius than argon.
    D. Two of the above.
    E. None of the above.

30. The partial pressures of CH_4, N_2, and O_2 in a sample of gas were found to be 171 mmHg, 505 mmHg, and 555 mmHg, respectively. Calculate the mole fraction of oxygen.

    A. 0.359 B. 0.410 C. 0.451 D. 0.730 E. 19.8

31. The half-life of a sample has been defined as the time it takes for half of a sample to decay. The fifth-life can be defined as the time it takes for one-fifth of a sample to decay. Given these definitions, calculate the fifth-life of a sample that has a first order half-life of 16 years.

    A. 5.2 years
    B. 10 years
    C. 18 years
    D. 26 years
    E. 37 years

32. Besides its ability to function as an acid, hydrosulfuric acid, H_2S, is able to act as a reducing agent. Which of the following equations illustrates this property?

    A. $H_2S(aq) + Cu^{2+}(aq) \rightarrow CuS(s) + 2\ H^+(aq)$
    B. $3\ H_2S(aq) + 2\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow 3\ S(s) + 2\ NO(g) + 4\ H_2O(l)$
    C. $H_2S(aq) + 2\ Na(s) \rightarrow H_2(g) + 2\ Na^+(aq) + S^{2-}(aq)$
    D. $H_2S(aq) + 2\ OH^-(aq) \rightarrow S^{2-}(aq) + 2\ H_2O(l)$
    E. $H_2S(aq) + 2\ AgI(s) \rightarrow Ag_2S(s) + 2\ H^+(aq) + 2\ I^-(aq)$

33. Heat is given off when hydrogen burns in air according to the equation

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

    Which of the following is responsible for the heat?

    A. Breaking hydrogen bonds gives off energy.
    B. Breaking oxygen bonds gives off energy.
    C. Forming hydrogen-oxygen bonds gives off energy.
    D. Both (A) and (B) are responsible.
    E. (A), (B), and (C) are responsible.

34. What is the approximate number of carbon atoms it would take placed next to each other to make a line that would cross this dot: ●

    A. 4
    B. 200
    C. 30,000,000
    D. 5.250×10^{18}
    E. 6.022×10^{23}

35. Which relationship or statement best describes $\Delta S°$ in J/K mol for the reaction below?

$$HgS\ (s) + O_2\ (g) \rightarrow Hg\ (l) + SO_2\ (g)$$

A. $\Delta S° \cong 0$
B. $\Delta S° < 0$
C. $\Delta S° > 0$
D. More than one of the above could be true
E. Not enough information provided

36. The popular over the counter antacid medication Zantac® can come as a solution that is 15 mg of Zantac® per mL of solution. The recommended dosage for an adult is between 5.0 and 10. mg per kilogram per day. What volume (in mL) should a 151 pound adult take per day if they take the average dosage?

A. 9.2 mL B. 34 mL C. 56 mL D. 69 mL E. 137 mL

37. Which one of the following statements about atomic structure and quantum numbers is **incorrect**?

A. In a given atom, the maximum number of electrons having principal quantum number n = 3, is 18.
B. The number of orbitals in a given *f* subshell is 7.
C. For n = 4, the largest possible value of l is 3.
D. For n = 4, the largest possible value of m_l is 2.
E. The following set of quantum numbers for a single orbital is not allowed: n=3, l=1, m_l= -2.

38. Nicotine, which comes from a tobacco plant, has a molecular mass of 162.2 g/mol and contains 8.70% hydrogen by mass. How many hydrogen atoms are in each nicotine molecule?

A. 7 B. 10 C. 12 D. 14 E. 16

39. What is the purpose of salt bridge in an electrochemical cell?

A. to maintain electrical neutrality in the half-cells via migration of ions.
B. to provide a source of ions to react at the anode and cathode.
C. to provide oxygen to facilitate oxidation at the anode.
D. to provide a means for electrons to travel from the anode to the cathode.
E. to provide a means for electrons to travel from the cathode to the anode.

40. A second-order reaction starts with an initial concentration of 0.020 M of the reactant. If the rate constant is 1.0×10^{-3} L/mol •s calculate the time required to decrease the initial concentration to 0.010 M.

A. 1.0×10^3 s
B. 2.5×10^3 s
C. 7.5×10^3 s
D. 1.0×10^4 s
E. 5.0×10^4 s