Worldwide Youth in Science and Engineering

2014 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. 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

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

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

$\Delta G° = -nF\varepsilon°$

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

$F = 96485$ 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 (State) – 2014

1. If a molecule is bent (V-shaped), what is its electron group geometry?

   A. Trigonal planar
   B. Tetrahedral
   C. Trigonal bipyramid
   D. Octahedral
   E. More than one of the above is possible.

2. Many commercial ice packs work via the reaction below. A barrier is broken that allows the ammonium chloride and water to mix, and the pack can then be used to cool injuries. What is the sign of ΔH for this reaction, and is it endothermic or exothermic?

$$NH_4Cl_{(s)} \xrightarrow{H_2O} NH_4Cl_{(aq)}$$

   A. Positive, exothermic
   B. Positive, endothermic
   C. Negative, exothermic
   D. Negative, endothermic
   E. Unable to determine with given information

3. What is the strongest intermolecular force that can be formed between a molecule of water (H_2O) and a molecule of ether ($H_3C\text{-}O\text{-}CH_3$)?

   A. Dipole-dipole
   B. Hydrogen bonding
   C. Van der Waals forces
   D. Dipole-induced dipole
   E. Ion-dipole

4. A 150.0 g mixture of sugar ($C_{12}H_{22}O_{11}$) and salt (NaCl) is 18.79% sodium by mass. What is the mass percent of chlorine in the mixture?

   A. 18.79% B. 28.97% C. 35.45% D. 43.46% E. 81.21%

5. In which of the following compounds is the mass percent of oxygen the highest?

   A. H_2O B. HNO_2 C. HNO_3 D. $HClO_4$ E. $C_6H_{12}O_6$

6. What is the total concentration of Ca^{2+} in a solution made by mixing 100.0 mL of 0.125 M $CaCl_2$ and 150.0 mL of 0.100 M Ca_3N_2? Assume the volumes are additive.

   A. 0.100 M B. 0.110 M C. 0.113 M D. 0.125 M E. 0.230 M

7. A gas sample in a closed container has a pressure of 433 mm Hg. If the volume of the container increases by a factor of 2.6, and the temperature of the sample is cut in half (as measured in Kelvin), what is the new pressure of the sample?

   A. 83.3 mm Hg B. 333 mm Hg C. 433 mm Hg D. 563 mm Hg E. 2250 mm Hg

8. When a 35.0 g sample of a solid cools from 85.0 ^{o}C to 25.9 ^{o}C, 5278 J are given off. What is the specific heat capacity of the solid?

   A. 0.0685 $\frac{J}{g*^{o}C}$ B. 1.77 $\frac{J}{g*^{o}C}$ C. 2.55 $\frac{J}{g*^{o}C}$ D. 5.82 $\frac{J}{g*^{o}C}$ E. 151 $\frac{J}{g*^{o}C}$

9. At 37 ^{o}C (body temperature), the pH of pure water is 6.80. Which of the following can be said of the autoionization of water?

   A. It is an endothermic process
   B. It is an exothermic process
   C. It is neither endo- nor exothermic
   D. More information is needed to determine.

10. Which of the following is **false** concerning reaction yields?

    A. Side reactions can lower the percent yield of desired reactions.
    B. Percent yield is the ratio of actual-to-theoretical yield expressed as a percentage.
    C. Actual yields tend to be higher than theoretical yields.
    D. Theoretical yields are determined by the limiting reagent of a reaction.
    E. The theoretical yield of a reaction represents the maximum amount of product that can be formed.

11. A gas container has a pressure of 20.0 atm. The gas is a mixture of O_2 and F_2, and the partial pressure of O_2 is 7.8 atm. If there are 10.0 moles of gas present, how many moles of F_2 are present?

    A. 2.2 mol B. 6.1 mol C. 7.8 mol D. 12.2 mol E. 15.6 mol

12. You have a glass containing 8.0 oz. (237 mL) of a 6.1 M solution of salt in contact with some solid salt. You add 125.0 mL of water to the glass dissolving a small portion of the solid present. What is the concentration of the resulting salt solution?

    A. 0.13 M B. 4.0 M C. 6.1 M D. 11.6 M E. 12.9 M

13. Consider the reaction below. If 15 molecules of H_2 are mixed with 10 molecules of O_2, and the reaction goes to completion, how many total molecules will be present in the reaction container?

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$

A. 25 molecules
B. 18 molecules
C. 14 molecules
D. 11 molecules
E. 10 molecules

14. Atoms in a molecule _____ interact; molecules in a mixture _____ interact, respectively.

A. Physically; physically
B. Chemically; chemically
C. Physically; chemically
D. Chemically; physically

15. A particular element has the ionization energies shown below. Which of the following is most likely this element?

IE_1	580 kJ/mol
IE_2	1815 kJ/mol
IE_3	2740 kJ/mol
IE_4	11600 kJ/mol
IE_5	14800 kJ/mol

A. Na B. Mg C. Al D. Si E. P

16. Beaker 1 contains a solution of a weak acid, HX, with a pH of 2.55. Beaker 2 contains a solution of a strong acid, HY, with a pH of 3.40. Which of the following **must** be true?

A. The solution in beaker 1 is more concentrated.
B. HX has a larger K_a value than HY.
C. The solution in beaker 2 has a greater volume.
D. HY is a weaker acid than HX.
E. Y^- is a stronger base than X^-.

17. How many moles of electrons are being transferred between species in the reaction below?

$$3Cl_{2(g)} + 2Cr^{3+}_{(aq)} + 7H_2O_{(l)} \rightarrow Cr_2O_7^{2-}{}_{(aq)} + 14H^+_{(aq)} + 6Cl^-_{(aq)}$$

A. 0 B. 1 C. 2 D. 3 E. 6

18. To display the photoelectric effect, the threshold frequency of metal 1 is 6.7×10^{14} Hz. For metal 2, the threshold frequency is 4.3×10^{14} Hz. Which of the following is **true**?

A. If both metals are hit with 4.3×10^{14} Hz light, both will eject electrons.
B. When both metals are hit with 1.0×10^{15} Hz light, electrons ejected from metal 1 will be moving faster than electrons ejected from metal 2.
C. When both metals are hit with 1.0×10^{15} Hz light of equal intensity, metal 1 will eject more electrons.
D. When both metals are hit with 1.0×10^{15} Hz light of equal intensity, metal 2 will eject more electrons.
E. The binding energy for metal 1 is greater than the binding energy for metal 2.

19. What is the molecular formula of 3-methylhexane?

A. C_6H_{12} B. C_6H_{14} C. C_7H_{14} D. C_7H_{16} E. C_7H_{17}

20. There are two isomers of the molecule XeF_2Cl_2. How could molecules of these two isomers be distinguished from each other?

A. Measure their polarity.
B. Identify their shape.
C. Measure their molecular weight.
D. Identify their ideal bond angles.
E. The two isomers will be identical in all properties.

21. Which of the following samples would have the least mass?

A. 0.250 mol S_8
B. 3.0 mol O_2
C. 1.06×10^{24} molecules of CH_4
D. 1.0 mol K
E. 4.5×10^{23} atoms of Pb

22. A beaker containing 900.0 mL of a 0.300 M solution is left on a hot plate overnight, causing 554 mL of solvent to evaporate. What is the new concentration of the solution?

A. 0.300 M B. 0.346 M C. 0.487 M D. 0.554 M E. 0.780 M

23. If the reaction below has a 63.2% yield, how many grams of copper can be formed by reaction of 1.573 g of Cu_2S with excess oxygen and carbon?

$$2Cu_2S_{(s)} + 3O_{2(g)} + 2C_{(s)} \rightarrow 4Cu_{(s)} + 2SO_{2(g)} + 2CO_{(g)}$$

A. 0.391 g B. 0.628 g C. 0.632 g D. 0.794 g E. 1.26 g

24. Solutions of ionic compounds are considered "ideal" when the solute completely dissociates into its constituent ions. In "non-ideal" solutions, a portion of the ions in solution remain paired rather than dissociating. How would the boiling point of an ideal 0.25 m NaCl solution compare to the boiling point of a non-ideal 0.25 m NaCl solution?

A. The two solutions would have the same boiling point.
B. The ideal solution would have a lower boiling point.
C. The ideal solution would have a higher boiling point.
D. The difference would depend on what the solvent was.
E. The difference must be determined experimentally.

25. If each of the following samples starts at the same temperature and absorbs 100.0 J of heat, which one will end up at the **highest** temperature? Specific heat capacities are given in parenthesis after each sample.

A. 0.500 g Cu (c = 0.39 J/g*K)
B. 0.500 g Fe (c = 0.45 J/g*K)
C. 0.500 g Ti (c = 0.52 J/g*K)
D. 0.500 g Pb (c = 0.13 J/g*K)
E. 0.500 g Al (c = 0.90 J/g*K)

26. Which species below would require the most energy to remove an electron?

A. Si^- B. P C. N D. C^- E. O^+

27. A basic solution is characterized by:

A. $[H_3O^+] < [OH^-]$
B. $[H_3O^+] = [OH^-]$
C. $[H_3O^+] > [OH^-]$
D. A pH of 7.00 at 25 ^oC.
E. More than one of the above is true for a basic solution.

28. How many neutrons are in an ^{208}Pb atom?

A. 82 B. 125 C. 126 D. 207 E. 208

29. In the reaction below, if species Y is being formed at a rate of 2.4 M/min, at what rate is species Z being formed?

$$2X_{(g)} \rightarrow 3Y_{(g)} + 5Z_{(g)}$$

A. 0.80 M/min B. 1.2 M/min C. 1.4 M/min D. 4.0 M/min E. 12 M/min

30. Given the steps below, what is the net reaction that would be observed experimentally?

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$
$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

A. $S_{(s)} + 2O_{2(g)} + SO_{2(g)} \rightarrow 2SO_{3(g)}$
B. $S_{(s)} + O_{2(g)} + SO_{2(g)} \rightarrow SO_{3(g)}$
C. $2S_{(s)} + 3O_{2(g)} \rightarrow 2SO_{3(g)}$
D. $S_{(s)} + 2SO_{3(g)} \rightarrow 3SO_{2(g)}$
E. $2SO_{2(g)} + O_{2(g)} + \rightarrow 2SO_{3(g)}$

31. The nuclide $^{208}_{81}Tl$ can be produced by α decay of what other nuclide?

A. $^{4}_{2}He$ B. $^{204}_{79}Au$ C. $^{297}_{80}Hg$ D. $^{210}_{82}Pb$ E. $^{212}_{83}Bi$

32. Which of the following is true concerning the nitrogen-oxygen bonds in NO_3^-?

A. One bond is expected to be stronger than the other two.
B. One bond is expected to be shorter than the other two.
C. One bond is expected to be longer than the other two.
D. It is predicted to have one triple and two single bonds.
E. All bonds are equivalent.

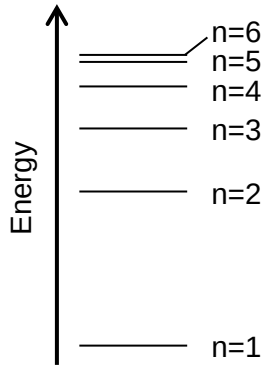
33. A 1.55 mol sample of NO_2 is put into a 0.350 L flask. After the reaction below has reached equilibrium, the concentration of N_2O_4 is 1.25 M. What is K_C for the reaction?

$2NO_{2(g)} \leftrightarrow N_2O_{4(g)}$

A. 0.0637 B. 0.336 C. 0.520 D. 0.648 E. 13.9

34. The figure on the right shows the electron energy level diagram for a hydrogen atom. Which of the following electronic transitions in a hydrogen atom would **<u>emit</u>** a photon with the **<u>largest</u>** frequency?

A. n = 1 → n = 6
B. n = 5 → n = 6
C. n = 2 → n = 1
D. n = 3 → n = 2
E. n = 5 → n = 4



35. Which of the following is the proper representation of a nickel atom with 30 neutrons and 26 electrons?

A. $^{30}_{28}Ni^{2-}$ B. $^{58}_{28}Ni^{2-}$ C. $^{30}_{28}Ni^{2+}$ D. $^{58}_{28}Ni^{2+}$ E. $^{58.69}_{28}Ni$

36. The gas-phase decomposition of N_2O_5 into NO_2 and O_2 is a first-order process with a rate constant of 1.50×10^{-3} s^{-1} at 55°C. A scientist places 10 g of N_2O_5 in Vessel 1 and 5.0 g of N_2O_5 in Vessel 2. Both vessels are at the same temperature and pressure. How much time is required for half of the N_2O_5 in each vessel to decompose?

A. Vessel 1 requires twice as much time as Vessel 2.
B. Vessel 1 requires half as much time as Vessel 2.
C. Vessel 1 requires three times as much time as Vessel 2.
D. Vessel 1 requires four times as much time as Vessel 2.
E. Vessel 1 requires the same amount of time as Vessel 2.

37. A particular particle has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$. Which of the following could be this particle?

A. A ground state V atom.
B. A ground state Cr^+ ion.
C. A ground state Mn^+ ion.
D. An excited state Cr^+ ion.
E. An excited state Mn^+ ion.

38. Which of the following is **<u>true</u>**?

A. The presence of polar bonds in a molecule makes the molecule polar.
B. The presence of lone pairs of electrons on the central atom of a molecule means the molecule will be polar.
C. The bond angles in NH_3 should be exactly 109.5^o.
D. Rotation around a double bond is prohibited.
E. A triple bond is composed of three sigma bonds.

39. When a Brønsted-Lowry acid is added to water it:

A. Increases $[H_3O^+]$.
B. Donates protons to water molecules.
C. Decreases $[OH^-]$.
D. Lowers the pH.
E. All of the above.

40. In a galvanic electrochemical cell:

A. Electrons travel from cathode to anode.
B. An external current is used to drive a reaction.
C. All of the reaction species are contained in a single beaker.
D. A spontaneous redox reaction is used to generate a current.
E. Cations diffuse toward the anode.