Worldwide Youth in Science and Engineering

2014 Academic Challenge

CHEMISTRY TEST - SECTIONAL

This Test Consists of 40 Questions

Chemistry Test Production Team
Jeremy Weaver, Emory University – Author/Team Leader
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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

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

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

$\Delta G° = -nF\varepsilon°$

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

$F = 96485$ 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 (Sectional) – 2014

1. According to the balanced reaction below, what volume of $CHCl_3$ can be produced by reaction of 0.750 L of HCl gas with excess CH_4 at 20.0 ^oC and a pressure of 1.00 atm?

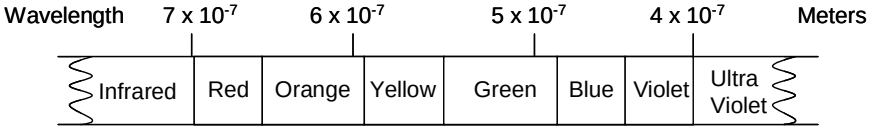
$$CH_{4(g)} + 3HCl_{(g)} \rightarrow CHCl_{3(g)} + 3H_{2(g)}$$

A. 0.250 L B. 0.750 L C. 1.00 L D. 2.25 L E. 3.00 L

2. What is the maximum number of neutral species that can be present in a single isoelectronic series of atom(s) and ion(s)?

A. 0 B. 1 C. 2 D. 3 E. There is no limit.

3. What color (A-E) of visible light is the most energetic?



A. Red B. Orange C. Yellow D. Green E. Blue

4. When 100.0 g of CuO is reacted with excess carbon by the reaction below, 0.580 mole of CO_2 are produced. What is the percent yield of this reaction?

$$2CuO_{(s)} + C_{(s)} \rightarrow 2Cu_{(s)} + CO_{2(g)}$$

A. 46.1 % B. 58.0 % C. 62.9 % D. 92.3 % E. 100.0 %

5. What is the molar mass of calcium phosphate ($Ca_3(PO_4)_2$)?

A. 87.0 g/mol
B. 135.0 g/mol
C. 215.0 g/mol
D. 310.2 g/mol
E. 365.1 g/mol

6. Which reaction below is an oxidation/reduction reaction?

A. $HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(l)}$
B. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
C. $MgCl_{2(aq)} + 2NaOH_{(aq)} \rightarrow Mg(OH)_{2(s)} + 2NaCl_{(aq)}$
D. $NH_{3(g)} \rightarrow NH_{3(l)}$
E. $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$

7. A sample of 1000 atoms of a particular element weighs 2.61×10^{-19} g. Identify the element.

A. H B. Gd C. Tb D. Ra E. Ac

8. Given the information below, find the value of ΔH_3.

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4PCl_{3(g)}$ $\Delta H_1 = -1148$ kJ
$PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)}$ $\Delta H_2 = +115$ kJ
$P_{4(s)} + 10Cl_{2(g)} \rightarrow 4PCl_{5(g)}$ $\Delta H_3 = ?$

A. -1608 kJ B. -1263 kJ C. -1033 kJ D. -688 kJ E. -460 kJ

9. How many milliliters of 0.863 M H_2SO_4 are required to completely react with 35.00 mL of 0.418 M $Ca(OH)_2$?

A. 8.48 mL B. 17.0 mL C. 33.9 mL D. 36.1 mL E. 72.3 mL

10. How many oxygen molecules are there in a 60.0 g sample of oxygen gas?

A. 3.75 molecules
B. 1.13×10^{24} molecules
C. 2.26×10^{24} molecules
D. 4.52×10^{24} molecules
E. 6.02×10^{23} molecules

11. Under what conditions is a gas expected to show the greatest deviations from ideality?

A. High temperature, high pressure
B. High temperature, low pressure
C. Low temperature, high pressure
D. Low temperature, low pressure
E. Gases always behave ideally

12. A 5.39 g sample of a particular compound is prepared in the laboratory. It is found to contain 3.37 g of carbon. A 4.79 g sample of the same compound is isolated from a plant specimen. How many grams of carbon does this second sample contain?

A. 0.625 g B. 2.02 g C. 2.99 g D. 3.37 g E. 4.79 g

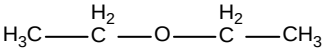
13. Which of the following molecules is isoelectronic with CO_2?

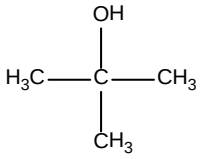
A. CO B. O_3 C. SiS_2 D. N_3^+ E. NO_2^+

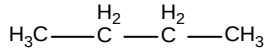
14. Which of the following must be true concerning a one-step, reversible, exothermic reaction?

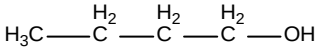
A. The activation energy of the forward reaction must be less than the activation energy of the reverse reaction.
B. It must obey a first-order rate law.
C. The dissociation of chlorine gas into chlorine atoms is a good example of this type of reaction.
D. It must be a gas phase reaction.
E. It must form only slightly-stable intermediates.

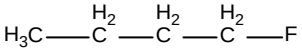
15. Which of the following compounds is predicted to have the greatest vapor pressure at room temperature? Assume all are liquids at room temperature. Lone pairs have been omitted for clarity.

A. 

B. 

C. 

D. 

E. 

16. A particular gas at 25 ^{o}C and a pressure of 0.500 atm has a density of 2.99 g/L. What is the molecular weight of the gas?

A. 12.3 g/mol B. 73.1 g/mol C. 134 g/mol D. 146 g/mol E. 621 g/mol

17. Which of the following solutions has the greatest total concentration of dissolved ions?

A. 0.700 M NaCl
B. 0.600 M $CaSO_4$
C. 0.500 M $MgCl_2$
D. 0.400 M Na_3PO_4
E. 0.300 M Ca_3N_2

18. For a solution of a non-volatile, nonelectrolyte, how many of the following will affect the boiling point of the solution?

I. The concentration of the solute
II. The identity of the solute
III. The identity of the solvent
IV. The molecular geometry of the solute

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

19. In a 1st-order decay process, what percentage of the original sample remains after 5 half-lives have passed?

A. 3.13 % B. 5.00 % C. 12.5 % D. 20.0 % E. 50.0 %

20. Which molecule below contains an atom with an sp^2-hybridized central atom?

A. PCl_5 B. SCl_2 C. SF_6 D. CO_2 E. SO_2

21. When 2.0 moles of H_2 and 1.0 mole of N_2 are mixed and allowed to react by the reaction below, what is the maximum mass of ammonia that can be formed?

$$3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$$

A. 1.3 g B. 2.0 g C. 23 g D. 32 g E. 34 g

22. In which of the following compounds does sulfur have the lowest (least positive or most negative) oxidation number?

A. SO_2 B. S_2O_3 C. $H_2S_4O_6$ D. H_2SO_4 E. H_2SO_3

23. Select the balanced equation representing the following reaction: gallium metal is heated with oxygen gas to form solid gallium(III) oxide.

A. $Ga_{(s)} + O_{2(g)} \rightarrow Ga_2O_{3(s)}$
B. $Ga_{(s)} + 3O_{(g)} \rightarrow GaO_{3(s)}$
C. $6Ga_{(s)} + O_{2(g)} \rightarrow 2Ga_3O_{(s)}$
D. $2Ga_{(s)} + 3O_{(g)} \rightarrow Ga_2O_{3(s)}$
E. $2Ga_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow Ga_2O_{3(s)}$

24. A particular element has a very negative first electron affinity and a very positive first ionization energy, and it's most stable ion is the X^- ion. To which group on the periodic table does this element belong?

A. Chalcogens
B. Halogens
C. Alkaline earth metals
D. Noble gases
E. Alkali metals

25. The _____ of an instrument determines how closely its measurements match the true value; the _____ of an instrument determines how closely repeated measurements match each other.

A. precision; precision
B. accuracy; accuracy
C. precision; accuracy
D. accuracy; precision
E. None of the above

26. A chemist finds a bottle of aqueous $CaCl_2$ on a shelf, but the concentration is not marked. To a small portion of this solution, she adds 0.250 g of $CaCl_2$, resulting in some solid on the bottom of the flask. She isolates this solid and finds it weighs 0.150 g. From this she can tell that the original solution was _____, and what she tested is now _____, respectively.

A. unsaturated, saturated
B. unsaturated, unsaturated
C. saturated, unsaturated
D. saturated, saturated
E. supersaturated, saturated.

27. In a particular reaction container, P_{CO} = 2.5 atm, P_{H_2} = 0.0530 atm, and P_{CH_3OH} = 0.935 atm. The compounds are related by the reaction below. Is this mixture at equilibrium? If not, which direction will it shift to achieve equilibrium?

$$CO_{(g)} + 2H_{2(g)} \leftrightarrow CH_3OH_{(g)} \qquad K_p = 50.0$$

A. Not at equilibrium, will shift toward reactants
B. Not at equilibrium, will shift toward products
C. At equilibrium, no shift
D. Not at equilibrium, no shift
E. Insufficient information given to determine

28. What is the approximate bond order of the bond in NO^-?

A. 0 B. 1 C. 1.5 D. 2 E. 2.5

29. What is the mass percent of carbon in caffeine ($C_8H_{10}N_4O_2$)?

A. 6.19% B. 27.9% C. 33.3% D. 49.5% E. 96.0%

30. VHF television stations broadcast in the range of 30 to 300 MHz. If a station operates at 165 MHz, what wavelength is it broadcasting?

A. 1.82 Mm B. 1.82 km C. 1.82 m D. 1.82 cm E. 1.82 mm

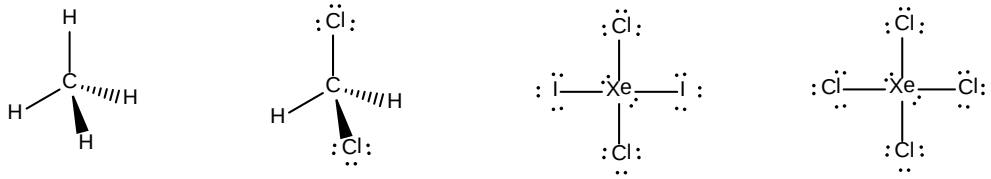
31. In naming the following compounds, which one would require a numerical prefix on <u>both</u> elements?

A. P_2O_5 B. Ca_3N_2 C. $MgCl_2$ D. NH_3 E. Al_2O_3

32. The specific heat capacity of water is 4.184 J/g* ^{o}C. How much energy is needed to raise a 357 g sample of water from 15.0 ^{o}C to 83.0 ^{o}C?

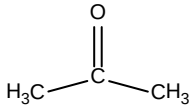
A. 0.285 kJ
B. 22.4 kJ
C. 24.3 kJ
D. 102 kJ
E. 124 kJ

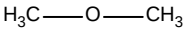
33. Given the following structures, how many of the molecules are polar?

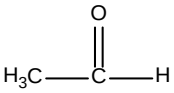


A. 0 (none are polar)
B. 1
C. 2
D. 3
E. 4 (all are polar)

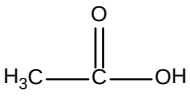
34. Which of the structures below shows a carboxylic acid? Note lone pairs are omitted for clarity.

A. 

B. 

C. 

D. 

E. 

35. For which of the following species is the molecular formula the same as the empirical formula?

A. H_2O_2 B. $C_3H_6O_3$ C. CH_3CO_2H D. C_6H_6 E. C_5H_5N

36. Some CH_4 is introduced into an empty flask and allowed to decompose by the reaction below. At equilibrium the concentration of CH_4 is 0.296 M. What is the equilibrium concentration of H_2?

$$CH_{4(g)} \leftrightarrow C_{(s)} + 2H_{2(g)} \qquad K = 1.15 \times 10^{-9}$$

A. 0.000 M
B. 3.40×10^{-10} M
C. 1.84×10^{-5} M
D. 3.68×10^{-5} M
E. 8.80×10^{-4} M

37. Some amount of $HClO_2$ is dissolved in pure water, producing a solution with a pH of 2.37. What is the concentration of ClO_2^- in this solution? The K_a of $HClO_2$ is 1.2×10^{-2}.

A. 1.5×10^{-3} M
B. 4.3×10^{-3} M
C. 5.8×10^{-3} M
D. 1.2×10^{-2} M
E. 2.4 M

38. Which of the following intermolecular forces is **not** present in a sample of dimethyl ether (CH_3-O-CH_3)?

A. London dispersion forces
B. Hydrogen bonding
C. van der Waals forces
D. Dipole-dipole forces
E. All of the above are present in a sample of dimethyl ether.

39. Given the rate law below, if the initial concentration of A is doubled, and the initial concentration of B is tripled, what will happen to the initial rate of the reaction?

$$\text{Rate} = k[A][B]^2$$

A. It increase by a factor of 2.
B. It will increase by a factor of 3.
C. It will increase by a factor of 6.
D. It will increase by a factor of 18.
E. It will not change.

40. How many electrons are in p-orbitals in a ground state Si atom?

A. 0 B. 2 C. 4 D. 8 E. 14