



**ENGINEERING
AT ILLINOIS**

2017 Academic Challenge

CHEMISTRY TEST – REGIONAL

– 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!

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Periodic Table of the Elements

1A																8A															
2A																3A															
1 H 1.008																5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00											
3 Li 6.941	4 Be 9.012															13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45											
11 Na 22.99	12 Mg 24.31																														
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	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	86 Rn (222)														
87 Fr (223)	88 Ra 226	89 Ac** (227)	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)															

*Lanthanides

**Actinides

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
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

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

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

$$P_{\text{solvent}} = X_{\text{solvent}} \cdot P^{\circ}_{\text{solvent}}$$

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

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

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

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

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

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

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

$$\Delta G^{\circ} = -nF\mathcal{E}^{\circ}$$

$$\Pi = MRT$$

$$F = 96485 \text{ C/mol}$$

$$R = 0.08206 \text{ L atm/mol K}; 8.3145 \text{ J/mol K}$$

$$1.0 \text{ kg} = 2.2 \text{ lb}$$

$$1.0 \text{ in} = 2.54 \text{ cm}$$

$$1 \text{ lb} = 453.59 \text{ g}$$

$$c = 2.998 \times 10^8 \text{ m/s}$$

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

$$S_{\text{gas}} = k_H \cdot P_{\text{gas}}$$

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

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

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

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

$$\text{pOH} = -\log [\text{OH}^-]$$

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

$$E_{\text{cell}}^{\circ} = E_{\text{red}}^{\circ} + E_{\text{ox}}^{\circ}$$

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

$$c = \lambda \nu$$

$$\Delta E = h \nu$$

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

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

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

$$1 \text{ atm} = 101,325 \text{ Pa} = 1.01325 \text{ bar}$$

$$1 \text{ J} = 1 \text{ N} \cdot \text{m} = 1 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} = 0.239 \text{ cal}$$

$$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

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.

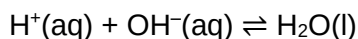
WYSE – Academic Challenge
Chemistry Test (Regional) – 2017

- When a fluorine atom becomes a fluoride ion
 - a proton is gained by the nucleus.
 - a proton is lost by the nucleus.
 - an electron is lost from one of the outer orbitals.
 - an electron is added to one of the outer orbitals.
 - an electron is added to the nucleus.
- What is the gram mass of $C_{12}H_{22}O_{11}$ in 60.0 mL of 0.0880 M solution?
 - 0.181 g
 - 1.81 g
 - 5.02 g
 - 5.28 g
 - none of these
- Rank the following solutions in the increasing order of osmotic pressure at 25 °C.
0.10 M $NaHCO_3$, 0.10 M $C_6H_{12}O_6$, 0.10 M $CaCl_2$, and 0.10 M Na_2SO_4
 - 0.10 M $CaCl_2$ = 0.10 M Na_2SO_4 < 0.10 M $NaHCO_3$ < 0.10 M glucose
 - 0.10 M glucose < 0.10 M $NaHCO_3$ < 0.10 M $CaCl_2$ < 0.10 M Na_2SO_4
 - 0.10 M glucose < 0.10 M $NaHCO_3$ < 0.10 M $CaCl_2$ = 0.10 M Na_2SO_4
 - 0.10 M glucose < 0.10 M $CaCl_2$ = 0.10 M Na_2SO_4 < 0.10 M $NaHCO_3$
 - 0.10 M glucose = 0.10 M $NaHCO_3$ = 0.10 M $CaCl_2$ = 0.10 M Na_2SO_4
- A compound, X, has a solubility of 79 g/100 g H_2O . when 55 g of X are added to 68 g of water followed by enough shaking, the resulting mixture will result in
 - a homogeneous solution
 - a heterogeneous mixture
 - a new compound
 - an element
 - none of these
- When viewed through a graduated cylinder, the curved surface of a liquid is called a _____.
 - min-max
 - display
 - measure line
 - dimple
 - meniscus
- What is the simplest alkane?
 - CH_3
 - CH_4
 - CO
 - C
 - CH_2

7. Which of the following elements has the largest ionization energy?

- A. Na B. Rb C. F D. K E. Ne

8. At a certain temperature for the reaction



$k_f = 1.4 \times 10^{11}$ and $k_r = 2.5 \times 10^{-5}$. What is K_c for this process at that temperature?

- A. 5.6×10^{15} B. 1.4×10^{11} C. 2.9×10^{-7} D. 3.5×10^6 E. 1.8×10^{-6}

9. Which of the following represents the correct formula of aluminum oxide?

- A. AlO B. Al_2O_3 C. AlO_2 D. Al_2O E. Al_3O_2

10. The initial rate of the reaction $\text{PCl}_5 \rightarrow \text{PCl}_3 + \text{Cl}_2$ is increased a factor of four when the concentration of PCl_5 is doubled. Therefore, the rate

- A. depends on the concentrations of PCl_3 and Cl_2 .
B. is first order with respect to PCl_5 .
C. is second order with respect to PCl_5 .
D. is fourth order with respect to PCl_5 .
E. is first order with respect to PCl_3 .

11. What is the number of protons in a molecule of CO_2 ?

- A. 3 B. 12 C. 16 D. 22 E. 32

12. Which of the following solutions have a concentration of nitrate ion (NO_3^-) greater than that in $0.0030 \text{ M Mg}(\text{NO}_3)_2$?

- I. $0.0025 \text{ M Al}(\text{NO}_3)_3$
II. 0.0040 M NaNO_3
III. $0.0036 \text{ M Ca}(\text{NO}_3)_2$
IV. $0.0054 \text{ M NH}_4\text{NO}_3$

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

13. When a substance undergoes a *chemical* change it is always true that

- A. it changes from a solid to a gas.
- B. it is converted to a new kind of matter with a different composition.
- C. the temperature of the substance increases.
- D. it liquefies.
- E. It evaporates.

14. How many milligrams are present in 0.20 decigrams?

- A. 20 mg B. 2000 mg C. 0.002 mg D. 0.00002 mg E. 200 mg

15. Which of the following pairs of elements would most likely form an ionic compound?

- A. P and Br B. Zn and K C. C and O D. Al and Rb E. F and Ca

16. Which of the following is the correct name for NaHCO_3 ?

- A. Sodium hydrogen carbon trioxide
- B. Sodium acetate
- C. Nitrogen hydrogen carbonate
- D. Sodium hydrogen carbonate
- E. Sodium hydro carbonate

17. Which of the following K_p expression does **not** match with the respective reaction?

- | | | |
|----|--|---|
| A. | $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$ | $K_p = \frac{P_{\text{CO}} \times P_{\text{H}_2\text{O}}}{P_{\text{CO}_2} \times P_{\text{H}_2}}$ |
| B. | $\text{C(graphite)} + \text{CO}_2\text{(g)} \rightleftharpoons 2 \text{CO(g)}$ | $K_p = \frac{(P_{\text{CO}})^2}{P_{\text{CO}_2}}$ |
| C. | $\text{NH}_4\text{HS(s)} \rightleftharpoons \text{NH}_3\text{(g)} + \text{H}_2\text{S(g)}$ | $K_p = P_{\text{NH}_3} \times P_{\text{H}_2\text{S}}$ |
| D. | $4 \text{CuO(s)} \rightleftharpoons 2 \text{Cu}_2\text{O(s)} + \text{O}_2\text{(g)}$ | $K_p = P_{\text{O}_2}$ |
| E. | $\text{H}_2\text{S(g)} + \text{I}_2\text{(s)} \rightleftharpoons 2 \text{HI(g)} + \text{S(s)}$ | $K_p = \frac{(P_{\text{HI}})^2}{P_{\text{H}_2\text{S}}}$ |

18. Consider the reaction $A \rightarrow \text{products}$. Which of the following plots is consistent with a zero-order reaction?
- A. $[A]$ plotted against time gives a horizontal, straight line.
 - B. $\ln [A]$ plotted against time gives a straight line of negative slope.
 - C. $1/[A]$ plotted against time gives a straight line of positive slope.
 - D. $[A]$ plotted against time gives a straight line of negative slope.
 - E. $[A]$ plotted against time gives a curved line of negative slope, decreasing in magnitude as time increases
19. For the elements silicon, sulfur, and tin; choose the appropriate characterization of the set's chemical symbols from the response list.
- A. All symbols start with the same letter.
 - B. All symbols have one letter.
 - C. All symbols have two letters.
 - D. All symbols start with a letter not the first letter of the element's English name.
 - E. No correct response.
20. An atomic element has an atomic mass of 35.5 amu. There are two naturally occurring isotopes of this atom. This means that:
- A. all atoms have masses of 35.5 amu.
 - B. more than half of all atoms have masses of 35.5.
 - C. 35.5 amu is the upper limit for the mass of an atom.
 - D. the mass of one isotope must be lighter than 35.5 amu while the mass of the other isotope is heavier than 35.5 amu.
 - E. none of the responses are correct.
21. If the concentration of $[H^+]$ in a dilute solution of nitric acid (HNO_3) is 0.00025 M, what is the pH of that solution?
- A. 2.5 B. 3.6 C. 6.3 D. 4.2 E. 3.3
22. Which of the following compounds is always a product of a combustion reaction of a hydrocarbon?
- A. a hydrocarbon
 - B. CO_2
 - C. oxygen
 - D. CO
 - E. carbon

23. A sample of nitrogen gas occupies a volume of 500 mL at a pressure of 0.971 atm. What volume will the gas occupy at a pressure of 1.50 atm, assuming the temperature remains constant?

- A. 342 mL B. 424 mL C. 324 mL D. 242 mL E. 500 mL

24. Which of the following is an endothermic process?

- A. Evaporation of water
B. Burning of wood
C. Explosion of dynamite
D. Discharging of a battery
E. Condensing water

25. Which of the following types of elements in the periodic table are always radioactive?

- A. Noble gases
B. Alkali metals
C. Halogens
D. Transition elements
E. Actinides

26. What is the percent composition of sodium in NaOH?

- A. 33.3% B. 57.5% C. 40.0% D. 2.75% E. 5.5%

27. Which atom is **least** likely to form an ion?

- A. Bromine, Br
B. Phosphorus, P
C. Argon, Ar
D. Carbon, C
E. Sodium, Na

28. What radiation type is shorter in wavelength than visible light radiation?

- A. Infrared
B. X-ray
C. Microwave
D. Radio
E. Visible light

29. C_2H_2 is _____ in the following reaction: $\text{C}_2\text{H}_2 + 2 \text{H}_2 \rightarrow \text{C}_2\text{H}_6$
- A. neutralized
 - B. electrolyzed
 - C. unreacted
 - D. oxidized
 - E. reduced
30. A covalent compound which is trigonal pyramidal in shape
- A. ammonia
 - B. water
 - C. sulfate ion
 - D. propane
 - E. methane
31. Coulomb's Law measures interactions between charged particles. Therefore, it most applies to what type of intermolecular interactions?
- A. hydrogen bonding
 - B. dispersion
 - C. ionic
 - D. dipole-dipole
 - E. pi stacking
32. The pH of a solution is 8.50. The concentration of $[\text{H}^+]$ in this solution is
- A. 8.50 M
 - B. $3.16 \times 10^{-8} \text{ M}$
 - C. $3.16 \times 10^{-9} \text{ M}$
 - D. $8.50 \times 10^{-8} \text{ M}$
 - E. 3.16 M
33. The reaction $4 \text{Fe} + 3 \text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3$ is what type of reaction?
- A. combination
 - B. decomposition
 - C. displacement
 - D. metathesis
 - E. combustion
34. In a sealed container at 1.0 atmosphere, the temperature of a sample of gas is raised from 300 K to 400 K. What will be the final pressure of the gas?
- A. 0.010 atm B. 1.0 atm C. 100 atm D. 1.33 atm E. 0.66 atm

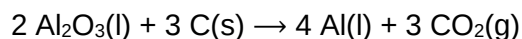
35. What is the empirical formula for a compound that contains 1.67 moles of carbon and 6.68 moles of hydrogen?

- A. CH B. CH₂ C. CH₃ D. CH₄ E. C₂H₄

36. Covalent bonds generally form between

- A. ions
B. metals
C. non-metals
D. metals and non-metals
E. salts

37. The overall reaction for the Hall-Heroult process is:



If the reaction is performed using 1.5 mol of Al₂O₃ as limiting reactant, how many moles of Al will be produced?

- A. 6.0 mol Al
B. 0.75 mol Al
C. 4.0 mol Al
D. 2.0 mol Al
E. 3.0 mol Al

38. What is the volume of 1.00 mole of a gas at standard temperature and pressure?

- A. 22.4 K B. 1.00 L C. 22.4 L D. 100 K E. 100 L

39. The process by which molecules on the surface of a liquid break away and go into gas phase is called

- A. evaporation
B. burning
C. condensation
D. freezing
E. sublimation

40. What is the mass of 1.500 mol of Fe₂O₃?

- A. 1.500 g B. 121.4 g C. 102.0 g D. 239.5 g E. 0.0065 g