



**ENGINEERING
AT ILLINOIS**

2018 Academic Challenge

CHEMISTRY TEST – SECTIONAL

– 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		2A		8A																																																															
1	2	3A	4A	5A	6A	7A	8	9	10	11	12	13	14	15	16	17	18																																																		
H 1.008	He 4.003	B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18	Al 26.98	Si 28.09	P 30.97	S 32.07	Cl 35.45	Ar 39.95	K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 52.00	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.69	Cu 63.55	Zn 65.38	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.90	Kr 83.80	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	(98)	Tc (98)	Ru 101.1	Rh 102.9	Pd 106.4	Ag 107.9	Cd 112.4	In 114.8	Sn 118.7	Sb 121.8	Te 127.6	I 126.9	Xe 131.3	Cs 132.9	Ba 137.3	La* 138.9	Hf 178.5	Ta 180.9	W 183.9	Re 186.2	Os 190.2	Pt 192.2	Au 197.0	Hg 200.6	Tl 204.4	Pb 207.2	Bi 209.0	Po (209)	At (210)	Rn (222)
87 Fr (223)	88 Ra Ac** (227)	89 Ra 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)	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																																		
*Lanthanides																																																																			
**Actinides																																																																			

Potentially Useful Information

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

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

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

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

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

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

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

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

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

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

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

$$\Pi = MRT$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$c = \lambda\nu$$

$$\Delta E = h\nu$$

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

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

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

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

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

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

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

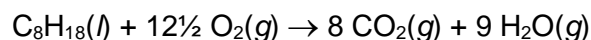
1. Most nitrates are soluble
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+ , Pb^{2+} , and Hg_2^{2+} .
4. Most sulfates are soluble with the exception of Ba^{2+} , Pb^{2+} , Hg_2^{2+} , and Ca^{2+}
5. 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 (Sectional) – 2018

1. The concentration of NaOH is 0.50 M. If 20 mL is needed to titrate 35 mL of a monoprotic acid, what is the concentration of the acid?
- A. 0.00286 M B. 0.875 M C. 0.286 M D. 0.00875 M E. 0.055 M
2. Assign the following reaction to one of the reaction classifications given in the response list:



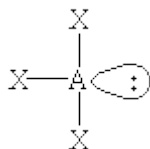
- A. exchange
B. combination
C. displacement
D. decomposition
E. precipitation
3. A sample of gas at 80 °C is cooled by 30 °C until its final volume is 1.75 L. If the pressure remains constant, what was the initial volume of the gas?
- A. 1.75 L B. 2.8 L C. 1.91 L D. 1.60 L E. 3.20 L
4. What is the enthalpy change for the following reaction?



$$\Delta H_f^\circ \text{ of } \text{C}_8\text{H}_{18}(l) = -269.7 \text{ kJ/mol}, \text{CO}_2(g) = -393.5 \text{ kJ/mol}, \text{H}_2\text{O}(g) = -241.8 \text{ kJ/mol}$$

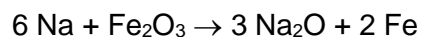
- A. -365.6 kJ
B. 905.0 kJ
C. -5593.9 kJ
D. 5054.5 kJ
E. -5054.5 kJ
5. The type(s) of radiation that consist(s) of charged particles include
- A. only α B. only β C. only γ D. α and β E. α and γ
6. Glucose has a chemical formula of $\text{C}_6\text{H}_{12}\text{O}_6$. What is the percent composition of hydrogen in this compound?
- A. 12
B. 50
C. 50
D. 20
E. 6.7

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?
- $5.96 \times 10^{14} \text{ s}^{-1}$
 - $-3.55 \times 10^{16} \text{ s}^{-1}$
 - 10.1 s^{-1}
 - $3.38 \times 10^{-17} \text{ s}^{-1}$
 - $2.96 \times 10^{16} \text{ s}^{-1}$
8. In a redox reaction, the oxidizing agent is the substance
- that contains an element that undergoes a decrease in oxidation number
 - that loses electrons
 - that is oxidized
 - no correct response
 - all are correct answers
9. If a central atom has three bonding pairs and a nonbonding pair of electrons attached to it (refer to the figure), the geometry about the central atom is



- triangular planar
 - tetrahedral
 - linear
 - trigonal pyramidal
 - octahedral
10. In hydrogen bonding, what could be the hydrogen bond acceptor?
- A very large molecule
 - The atom in the molecule to which hydrogen is attached
 - A highly electronegative atom with lone pair electrons
 - An exposed hydrogen atom nucleus
 - A metal atom
11. A solution of an acid is mixed with a solution of a base. The neutral mixture that results contains magnesium nitrate ($\text{Mg}(\text{NO}_3)_2$). This mixture could have resulted from the combination of which of these pairs of solutions?
- a solution of MgO and a solution of NH_3
 - a solution of $\text{Mg}(\text{OH})_2$ and a solution of HNO_3
 - a solution of MgO and a solution of HNO_2
 - a solution of $\text{Mg}(\text{OH})_2$ and a solution of NH_3
 - a solution of Mg and a solution of NO_3

12. If you are provided 200 g of sodium and 250 g of iron(III) oxide, how much of the iron(III) oxide is used up according to the following reaction?

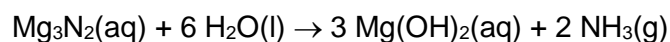


- A. 125 g B. 250 g C. 231 g D. 38.5 g E. 450 g
13. At a factory near the coast (at sea level, where air pressure is 1.0 atm), 1.00 mole of chlorine gas, Cl_2 , is pumped into a steel tank in a large walk-in refrigerator at 4.0°C . What is the density of the chlorine gas in this condition?
- A. 3.52 g/L B. 3.12 g/L C. 0.32 g/L D. 1.56 g/L E. 0.22 g/L
14. What is the amount of work done when a gas expands from 1.00 L to 3.00 L against a constant external pressure of 1.00 atm? Use $1 \text{ L}\cdot\text{atm} = 101 \text{ J}$.
- A. -202 J
 B. 101 J
 C. -101 J
 D. 202 J
 E. 404 J
15. There are two isotopes of element "X". Following is a list of each isotope, their mass and abundance. What is the weighted atomic mass of "X"?

Isotope	Mass (amu)	% Abundance
#1	34.96885	75.771
#2	36.96590	24.229

- A. 35.453 amu
 B. 49.545 amu
 C. 26.496 amu
 D. 35.967 amu
 E. 36.966 amu
16. What are the values for m_l for a "d" orbital?
- A. 0, 1, 2, 3, 4
 B. $-1, 0, 1$
 C. 0, 1, 2, 3
 D. $-2, -1, 0, 1, 2$
 E. 0, 1, 2
17. Which of the following statements concerning oxidation and reduction is correct?
- A. they cannot occur independently of each other
 B. they describe, respectively, the gain and loss of electrons
 C. they accompany all chemical changes
 D. no correct response
 E. all responses are correct

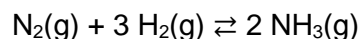
18. The attraction of an atom for a pair of shared electrons is called its
- A. covalence
 - B. valence
 - C. polarity
 - D. dipole
 - E. electronegativity
19. Certain conditions can alter the boiling point of a liquid. To what conditions does the normal boiling point of a liquid refer?
- A. The boiling point at normal pressure
 - B. The boiling point at constant pressure
 - C. The boiling point at vapor pressure
 - D. The boiling point at atmospheric pressure
 - E. The boiling point at vapor pressure
20. If you have 5 mol Mg_3N_2 and 6 mol H_2O , how many moles of $\text{Mg}(\text{OH})_2$ would be produced?



- A. 2 g $\text{Mg}(\text{OH})_2$
 - B. 3 mol $\text{Mg}(\text{OH})_2$
 - C. 15 g $\text{Mg}(\text{OH})_2$
 - D. 15 mol $\text{Mg}(\text{OH})_2$
 - E. 2 mol $\text{Mg}(\text{OH})_2$
21. Organic compounds containing a carbon-oxygen double bond include all of the following except _____.
- A. aldehyde
 - B. ether
 - C. ketone
 - D. ester
 - E. none of the above
22. A positive ion is formed as a result of an atom
- A. losing one or more protons
 - B. losing one or more electrons
 - C. losing one or more neutrons
 - D. gaining one or more protons
 - E. gaining one or more electrons

23. A sample of metal weighs 6.25 g. When a student places it into a graduated cylinder containing water, the liquid level rises from 20.25 mL to 28.47 mL. What is the density of the metal?
- A. 0.312 g/mL
 - B. 0.200 g/mL
 - C. 0.309 g/mL
 - D. 1.32 g/mL
 - E. 0.760 g/mL
24. The boiling of water is a
- A. chemical change because heat is needed for the process to occur.
 - B. chemical change because a gas (steam) is given off.
 - C. chemical and physical change.
 - D. physical change because the gaseous water is chemically the same as the liquid.
 - E. physical change because the water merely disappears.
25. Calcium reacts with a certain element (X) to form a compound with the general formula CaX . What would the most likely formula be for the compound formed between lithium and element X?
- A. Li_2X
 - B. LiX_2
 - C. Li_2X_3
 - D. Li_2X_2
 - E. LiX
26. With respect to its electron configuration, an alkali metal atom _____.
- A. has one electron in its outer shell
 - B. has two electrons in its outer shell
 - C. has a filled outer shell
 - D. is one electron short of having a filled outer shell
 - E. is two electrons short of having a filled outer shell
27. How many grams of magnesium nitrate are required to produce 250.0 mL of a 0.0750 M solution?
- A. 1.61 g
 - B. 1.39 g
 - C. 2.19 g
 - D. 0.800 g
 - E. 2.78 g
28. What is the osmotic pressure of a 0.075 M solution of sucrose at 18.5 °C?
- A. 0.114 atm
 - B. 1.36 atm
 - C. 18.0 atm
 - D. 1.80 atm
 - E. 11.4 atm
29. For a certain first order reaction, it is found that it takes 156 seconds for the concentration of reactant to fall from 0.100 M to 0.0500 M. How much time would it take for the concentration of reactant to fall from 0.0500 M to 0.0250 M?
- A. 156 s
 - B. 76.0 s
 - C. 312 s
 - D. 12.5 s
 - E. 89.6 s

30. Nitrogen reacts with hydrogen to form ammonia, according to the following equation:



At a certain temperature the equilibrium constant is $K_c = 2.0$. An equilibrium mixture is found to contain concentrations of N_2 equal to 0.15 M and H_2 equal to 0.30 M . What is the concentration of NH_3 in this mixture?

- A. $2.7 \times 10^{-2} \text{ M}$
- B. 0.16 M
- C. $8.1 \times 10^{-3} \text{ M}$
- D. $9.0 \times 10^{-2} \text{ M}$
- E. $5.2 \times 10^{-3} \text{ M}$

31. How many total electrons are present in a nitride ion?

- A. 4
- B. 7
- C. 10
- D. 8
- E. 5

32. To what decimal position should a measurement be recorded if the smallest markings on the measurement scale are tenths of a centimeter?

- A. to the closest centimeter
- B. to the tenths of a centimeter
- C. to the hundredths of a centimeter
- D. to the thousandths of a centimeter
- E. the measurement cannot be determined

33. What is the correct formula for ammonium sulfide?

- A. NH_4SO_3
- B. $(\text{NH}_4)_2\text{SO}_4$
- C. N_2S_3
- D. NH_3S
- E. $(\text{NH}_4)_2\text{S}$

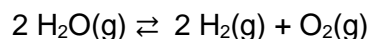
34. In general, ionization energy _____ as you go down, and _____ as you go from left to right across the periodic table.

- A. decreases, decreases
- B. decreases, increases
- C. increases, decreases
- D. increases, increases
- E. cannot be determined

35. The solubility of a gas in general _____ with increasing pressure.

- A. increases
- B. decreases
- C. remains the same
- D. decreases and then increases
- E. In order to determine an answer one must know the identity of the gas in question.

36. Consider the gas-phase equilibrium system represented by the equation:



If the forward reaction (left to right) is endothermic, which of the following changes will decrease the equilibrium amount of H_2O ?

- A. adding more oxygen
 - B. adding a solid phase catalyst
 - C. decreasing the volume of the container (the total pressure increases)
 - D. increasing the temperature at constant pressure
 - E. adding He gas
37. For the chemical reaction $\text{A} \rightarrow \text{C}$, a plot of $1/[\text{A}]_t$ versus time was found to give a straight line with a positive slope. What is the order of reaction?
- A. zeroth
 - B. first
 - C. second
 - D. third
 - E. such a plot cannot reveal the order of the reaction
38. An atom has an atomic number of 11 and a mass number of 23. Which of the following statements is correct?
- A. It has 11 protons, 11 electrons, 11 neutrons, and is vanadium.
 - B. It has 11 protons, 12 electrons, 11 neutrons, and is sodium.
 - C. It has 11 protons, 11 electrons, 12 neutrons, and is sodium.
 - D. It has 11 protons, 12 electrons, 12 neutrons, and is magnesium.
 - E. It has 11 protons, 11 electrons, 23 neutrons, and is vanadium.
39. What is the molarity of a NaNO_3 solution made by diluting 250.0 mL of a 1.60 M solution to a final volume of 400. mL?
- A. 1.20 M
 - B. 1.00 M
 - C. 0.200 M
 - D. 0.160 M
 - E. 2.56 M
40. The rate constant of a first-order process that has a half-life of 225 s is _____ s^{-1} .
- A. 0.693
 - B. 12.5
 - C. 1.25
 - D. 4.44×10^{-3}
 - E. 3.08×10^{-3}