



**ENGINEERING  
AT ILLINOIS**

## 2018 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. 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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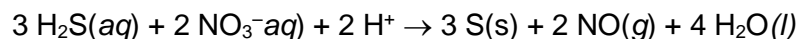
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WYSE – Academic Challenge  
Chemistry Test (State) – 2018

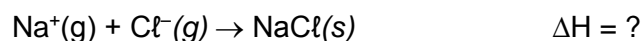
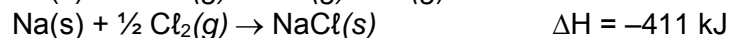
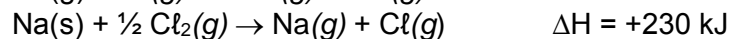
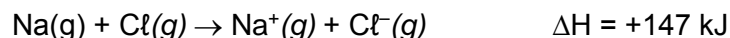
1. When added to water, which of the following will not produce a base?
- A. MgO                      B. CaO                      C. BaO                      D. Na<sub>2</sub>O                      E. CO<sub>2</sub>
2. Which of the following correctly identifies the oxidizing agent and the reducing agent?



- A. H<sub>2</sub>S is the oxidizing agent. H<sup>+</sup> is the reducing agent.  
B. NO<sub>3</sub><sup>-</sup> is the oxidizing agent. H<sub>2</sub>S is the reducing agent.  
C. H<sub>2</sub>S is the oxidizing agent. H<sub>2</sub>O is the reducing agent.  
D. NO is the oxidizing agent. NO<sub>3</sub><sup>-</sup> is the reducing agent.  
E. H<sup>+</sup> is the oxidizing agent. NO<sub>3</sub><sup>-</sup> is the reducing agent.
3. Suppose that 2.3 L of gas at 35 °C and 1.0 atm is expanded to 4.5 L at 42 °C. What will the final pressure of the gas be?

- A. 0.61 atm                      B. 0.40 atm                      C. 0.52 atm                      D. 0.75 atm                      E. 0.95 atm

4. From the given information, calculate the enthalpy change for the formation of sodium chloride.



- A. +34 kJ                      B. +788 kJ                      C. -34 kJ                      D. -788 kJ                      E. -558 kJ
5. The mass number remains constant during which of the following modes of decay?
- A. α type                      B. β type                      C. γ type                      D. α and β                      E. α and γ
6. A compound is found to contain 1.121 g nitrogen, 0.161 g hydrogen, 0.480 g carbon and 0.640 g oxygen. What is its empirical formula?

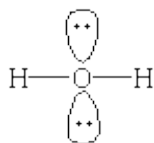
- A. C<sub>4</sub>H<sub>4</sub>N<sub>5</sub>O  
B. CH<sub>4</sub>N<sub>2</sub>O  
C. C<sub>2</sub>HN<sub>2</sub>O  
D. CH<sub>2</sub>N<sub>2</sub>O<sub>3</sub>  
E. CH<sub>4</sub>N<sub>2</sub>O

7. What wavelength of light will be emitted from a hydrogen atom when its electron drops from an energy level of  $n = 4$  to an energy level of  $n = 3$ ?
- $6.75 \times 10^4 \text{ m}$
  - $1.60 \times 10^{14} \text{ m}$
  - $1.17 \times 10^{-20} \text{ m}$
  - $5.33 \times 10^5 \text{ m}$
  - $1.88 \times 10^{-6} \text{ m}$

8. Which of the following statements concerning redox reactions is incorrect?

- The oxidizing agent loses electrons.
- The reducing agent is the substance being oxidized.
- The substance oxidized loses electrons.
- The oxidizing agent is the substance being reduced.
- The oxidizing agent gains electrons.

9. The shape of a water molecule is



- bent
- linear
- unknown
- tetrahedral
- octahedral

10. Which arrangement of the solids is listed in order of overall hardness and melting point starting with lowest first?

- ionic solids, covalent network solids, molecular solids
- covalent network solids, ionic solids, molecular solids
- ionic solids, molecular solids, covalent network solids
- molecular solids, ionic solids, covalent network solids
- all answers are correct

11. Which of the following reactions would produce a salt that is acidic in aqueous solution?

- 1 mol  $\text{Ba}(\text{OH})_2$  & 2 mol  $\text{HCl}$
- 1 mol  $\text{HF}$  & 1 mol  $\text{LiOH}$
- 1 mol  $\text{H}_2\text{SO}_4$  & 2 mol  $\text{NH}_3$
- 1 mol  $\text{HCl}$  & 1 mol  $\text{NaOH}$
- 1 mol  $\text{H}_2\text{CO}$  & 2 mol  $\text{NaOH}$

12. A helium balloon with a volume of 2.4 L contains 0.10 mole of gas at  $25^\circ\text{C}$  and 1 atm of pressure. The balloon leaks 0.02 mole of gas until someone manages to seal the hole. What is the new volume of the balloon?

- 1.9 L
- 0.5 L
- 19.2 L
- 3.0 L
- 7.5 L

13. Which statement about a spontaneous process is **not** true?
- A spontaneous process always has a reverse process that is considered nonspontaneous.
  - When heat is used to propel an event (such as a chemical reaction) the event cannot be considered spontaneous.
  - A spontaneous process is not defined by the speed of the event.
  - A spontaneous process proceeds naturally without intervention.
  - A negative enthalpy change is the major contributor to a spontaneous process.
14. The elemental analysis of a medicine determines that it contains 75.7% C, 8.80% H, and 15.5% O. The molar mass is determined to be 412 g/mol. What is the multiplicity of the empirical formula in this compound?
- 1
  - 2
  - 3
  - 4
  - 5
15. What are the permissible values for the angular quantum number ( $l$ ) when  $n = 4$ ?
- 1, 2, 3
  - 0, 1, 2
  - 1, 2, 3, 4
  - 0, 1, 2, 3
  - 0, 1, 2, 3, 4
16. Which one is the spectator ion in the following reaction?
- $$\text{Cl}_2(g) + 2 \text{Na}^+(aq) + 2 \text{Br}^-(aq) \rightarrow 2 \text{Na}^+(aq) + 2 \text{Cl}^-(aq) + \text{Br}_2(l)$$
- $\text{Br}^-(aq)$
  - $\text{Cl}_2(g)$
  - $\text{Na}^+(aq)$
  - $\text{Br}_2(l)$
  - $\text{Cl}^-(aq)$
17. What is the bond angle value in the VSEPR geometry of phosphorus trichloride ( $\text{PCl}_3$ )?
- $180^\circ$
  - $120^\circ$
  - $90^\circ$
  - $107^\circ$
  - none is correct
18. If you are provided 200 g of sodium and 250 g of iron(III) oxide, how much of the iron(III) oxide will be left over according to the following reaction?
- $$6 \text{Na} + \text{Fe}_2\text{O}_3 \rightarrow 3 \text{Na}_2\text{O} + 2 \text{Fe}$$
- 232 g
  - 19 g
  - 250 g
  - 125 g
  - 100 g
19. The type of chemical reaction that requires heat to produce product is called \_\_\_\_\_
- endothermic
  - exothermic
  - synthesis
  - both A and B
  - both B and C

20. The following table shows the formula and phase at room temperature of three substances. All three are held together by London dispersion forces. What is the reason for such difference in the physical states?

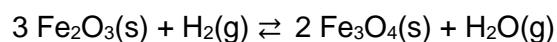
Chemical	$\text{Cl}_2$	$\text{Br}_2$	$\text{I}_2$
Phase at 25 °C	gas	liquid	solid

- A. The bonds in bromine are somewhat polar due to the difference in electronegativity. The bonds in iodine are even more polar.
- B. All bromine contains a few  $\text{Br}_3^-$  ions and iodine contains even more  $\text{I}_3^-$  ions.
- C. The halogens constantly exchange electrons making the bonds slightly ionic in character.
- D. The electron clouds around bromine and iodine are not easy to distort, thus the liquid and solid phases happen as a result.
- E. The electron clouds around bromine and iodine are large and easy to distort, so it is easy to induce temporary dipole moments causing the attraction between the neighboring molecules.
21. How many carbon atoms are present in the alkane whose IUPAC name is 2,2,4-trimethylheptane?
- A. eight                      B. seven                      C. nine                      D. ten                      E. nine
22. Which of the following ions is not isoelectronic with the noble gas neon?
- A.  $\text{Na}^+$                       B.  $\text{F}^-$                       C.  $\text{C}^{4+}$                       D.  $\text{N}^{3-}$                       E.  $\text{O}^{2-}$
23. If an object has a density of  $7.62 \text{ g/cm}^3$ , what is its density in units of  $\text{kg/m}^3$ ?
- A.  $7.62 \times 10^3 \text{ kg/m}^3$
- B.  $7.62 \times 10^{-7} \text{ kg/m}^3$
- C.  $7.62 \times 10^{-3} \text{ kg/m}^3$
- D.  $7.62 \times 10^1 \text{ kg/m}^3$
- E.  $7.62 \times 10^{-1} \text{ kg/m}^3$
24. In which of the following pairs of properties are both physical properties?
- A. melts at  $86^\circ\text{C}$ , decomposes upon heating
- B. good reflector of light, magnetic
- C. has a high density, reacts easily with bromine
- D. malleable, toxic at low doses
- E. no correct response
25. The correct formula for ammonium carbonate is \_\_\_\_\_.
- A.  $(\text{NH}_4)_2\text{CO}_3$                       B.  $\text{NH}_4\text{CO}_2$                       C.  $(\text{NH}_3)_2\text{CO}_4$                       D.  $(\text{NH}_3)_2\text{CO}_3$                       E.  $\text{N}_2(\text{CO}_3)_3$

26. The atomic radius of main-group elements generally increases down a group because \_\_\_\_\_.
- A. effective nuclear charge increases down a group
  - B. both effective nuclear charge increases down a group and the principal quantum number of the valence orbitals increases
  - C. effective nuclear charge decreases down a group
  - D. the principal quantum number of the valence orbitals increases
  - E. effective nuclear charge zigzags down a group
27. How many grams of a 7.00% by weight NaCl solution are necessary to yield 4.60 g NaCl?
- A. 0.320 g solution
  - B. 65.7 g solution
  - C. 152 g solution
  - D. 46.1 g solution
  - E. 18.9 g solution
28. Assuming that all solutes in solution are nonvolatile, which of the following aqueous solutions would have the highest boiling point?
- A. 1 molal glucose
  - B. 2 molal glucose
  - C. 0.5 molal glucose
  - D. 1 molal potassium chloride
  - E. 1 molal calcium chloride
29. Consider the following reaction at equilibrium:
- $$2 \text{CO}_2(g) \rightleftharpoons 2 \text{CO}(g) + \text{O}_2(g) \quad \Delta H^\circ = -514 \text{ kJ}$$
- Le Châtelier's principle predicts that an increase in temperature will \_\_\_\_\_.
- A. increase the concentration of  $\text{O}_2(g)$
  - B. increase the concentration of  $\text{CO}_2(g)$
  - C. increase the concentration of  $\text{CO}(g)$
  - D. decrease the concentration of  $\text{CO}_2(g)$
  - E. have no effect on reactant and product concentrations
30. It takes 42.0 min for the concentration of a reactant in a first-order reaction to drop from 0.45 M to 0.32 M at 25 °C. How long will it take for the reaction to be 90% complete?
- A. 13.0 min
  - B. 86.0 min
  - C. 137 min
  - D. 222 min
  - E. 284 min

31. The ion of an element has a positive charge of 3. The mass number of the atom is 27 and the number of neutrons is 14. What is the number of electrons in the ion?
- A. 10                      B. 13                      C. 14                      D. 16                      E. 19
32. The outside air temperature is 65 °F, what is the temperature in Kelvin?
- A. 313 K                      B. 332 K                      C. 327 K                      D. 291 K                      E. 338 K
33. The correct name for  $\text{Cu}(\text{CN})_2$  is \_\_\_\_\_.
- A. copper(I) cyanide  
B. carbon cyanide  
C. carbon carbonate  
D. copper(II) cyanide  
E. copper(I) nitride
34. For which of the properties does lithium have a larger value than potassium?
- A. molecular weight  
B. atomic radius  
C. ionic radius  
D. number of protons  
E. first ionization energy
35. Which one of the following is most soluble in hexane ( $\text{C}_6\text{H}_{14}$ )?
- A.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$   
B.  $\text{CH}_3\text{OH}$   
C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$   
D.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$   
E.  $\text{CH}_3\text{CH}_2\text{OH}$
36. How many grams of pyrazine ( $\text{C}_4\text{H}_4\text{N}_2$ ) would have to be dissolved in 2.50 kg of carbon tetrachloride to lower the freezing point by 6.1 °C? The freezing point depression constant for carbon tetrachloride is 30 °C/m.
- A. 0.51 g  
B. 41 g  
C. 78 g  
D. 0.20 g  
E. 82 g

37. At equilibrium, in the following reaction at 303 K, the total pressure is 0.076 atm and the partial pressure of  $\text{H}_2$  is found to be 0.021 atm.

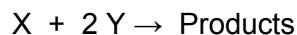


What is the  $K_p$  for the reaction?

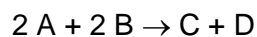
- A.  $1.2 \times 10^{-3}$                       B. 3.6                      C. 2.6                      D.  $1.6 \times 10^{-3}$                       E. 5.2



38. Consider the following hypothetical reaction, which is found to be first order in X and second order in Y. What are the units on k, the specific rate constant, if the reaction rate is expressed in units of M/s?



- A.  $M \cdot s^{-1}$   
 B.  $M^{-1} \cdot s^{-1}$   
 C.  $M^{-3} \cdot s^{-1}$   
 D.  $M^2 \cdot s^{-1}$   
 E.  $M^{-2} \cdot s^{-1}$
39. When Ernest Rutherford shot a beam of alpha particles at a sheet of gold foil, a few of the particles were deflected. This observation \_\_\_\_\_.
- A. led to the discovery of the atomic nucleus  
 B. confirmed the presence of electrons  
 C. was the basis for Thomson's plum-pudding model of the atom  
 D. utilized the deflection of beta particles by gold foil  
 E. proved the law of multiple proportions
40. What is the rate equation for the following reaction and experimental data?



Experiment	[A]	[B]	Initial Rate of Formation of C (mol.L <sup>-1</sup> .min <sup>-1</sup> )
1	0.60	0.15	$6.3 \times 10^{-3}$
2	0.20	0.60	$2.8 \times 10^{-3}$
3	0.20	0.15	$7.0 \times 10^{-4}$

- A. rate =  $k[A]^1[B]^1$   
 B. rate =  $k[A]^1[B]^2$   
 C. rate =  $k[A]^2[B]^1$   
 D. rate =  $k[A]^2[B]^0$   
 E. rate =  $k[A]^0[B]^2$