

**FACULTY OF SCIENCE**

DEPARTMENT OF CHEMICAL SCIENCES
B-ENG. B-Eng. Tech in Physical Metallurgy/ Extraction Metallurgy
MODULE: Chemistry 1 (Theory) (Extended)

MODULE ECMSED1
ENGINEERING CHEMISTRY 1A (THEORY)

CAMPUS DFC

SUPPLEMENTARY EXAMINATION

DATE: JANUARY 2020

SESSION: 08.00-11.00

ASSESSORS

DR C ZVINOWANDA
PROF X. Y. MBIANDA
DR A. LEUDJO TAKA

INTERNAL MODERATOR

PROF K. PILLAY

DURATION 180 MINUTES

MARKS 150

NUMBER OF PAGES: 13 PAGES, INCLUDING A DATA SHEET AND PERIODIC TABLE.

INSTRUCTIONS: ANSWER SECTION A ON THE MULTIPLECHOICE ANSWER SHEET.

ANSWER SECTION B IN THE ANSWER BOOKLETS PROVIDED:

CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).

GIVE ALL NUMERICAL ANSWERS TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES AND WITH APPROPRIATE UNITS.

REQUIREMENTS:

SECTION A: MULTIPLE CHOICE ANSWER SHEET

SECTION B: USE ANSWER BOOKLETS:

SECTION A**ANSWER THIS SECTION ON THE MULTIPLE-CHOICE ANSWER SHEET**

1. For which of the following, can the composition vary?
 - A. pure substance
 - B. element
 - C. both homogeneous and heterogeneous mixtures
 - D. homogeneous mixture
 - E. heterogeneous mixture

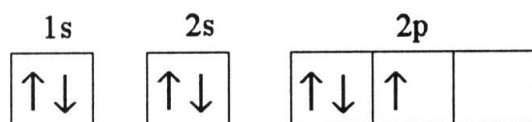
2. Which combination of protons, neutrons, and electrons is correct for the isotope of copper, $^{63}_{29}\text{Cu}$?
 - A. 29 p+, 34 n°, 29 e-
 - B. 29 p+, 29 n°, 63 e-
 - C. 63 p+, 29 n°, 63 e-
 - D. 34 p+, 29 n°, 34 e-
 - E. 34 p+, 34 n°, 29 e-

3. Of the reactions below, which one is not a combination reaction?
 - A. $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
 - B. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
 - C. $2\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$
 - D. $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$
 - E. $2\text{CH}_4 + 4\text{O}_2 \rightarrow 2\text{CO}_2 + 4\text{H}_2\text{O}$

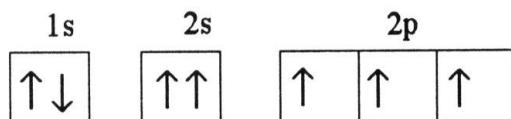
4. One million argon atoms is _____ mol (rounded to two significant figures) of argon atoms.
 - A. 3.0
 - B. 1.7×10^{-18}
 - C. 6.0×10^{23}
 - D. 1.0×10^{-6}
 - E. $1.0 \times 10^{+6}$

5. What are the spectator ions in the reaction between KCl (aq) and $\text{AgNO}_3 \text{ (aq)}$?
- A. K^+ and Ag^+
B. Ag^+ and Cl^-
C. K^+ and NO_3^-
D. Ag^+ and NO_3^-
E. K^+ only
6. When aqueous solutions of AgNO_3 and KI are mixed, silver iodide precipitates. The balanced net ionic equation is _____.
- A. $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$
B. $\text{Ag}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) \rightarrow \text{AgNO}_3(\text{s})$
C. $\text{Ag}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) \rightarrow \text{AgNO}_3(\text{aq})$
D. $\text{AgNO}_3(\text{aq}) + \text{KI}(\text{aq}) \rightarrow \text{AgI}(\text{s}) + \text{KNO}_3(\text{aq})$
E. $\text{AgNO}_3(\text{aq}) + \text{KI}(\text{aq}) \rightarrow \text{AgI}(\text{aq}) + \text{KNO}_3(\text{s})$
7. All of the orbitals in a given electron shell have the same value as the _____ quantum number.
- A. principal
B. angular momentum
C. magnetic
D. spin
E. psi
8. Which one of the following is the correct electron configuration for a ground-state nitrogen atom?

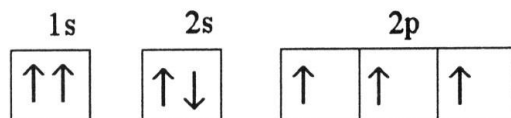
A.



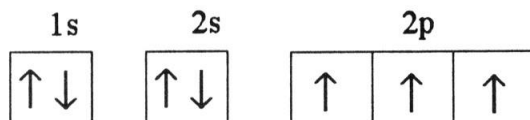
B.



C.



D.



E. None of the above is correct.

9. In which set of elements would all members be expected to have very similar chemical properties?

- A. O, S, Se
- B. N, O, F
- C. Na, Mg, K
- D. S, Se, Si
- E. Ne, Na, Mg

10. Of the following elements, _____ has the most negative electron affinity.

- A. S
- B. Cl
- C. Se
- D. Br
- E. I

11. Which of the following has the bonds correctly arranged in order of increasing polarity?

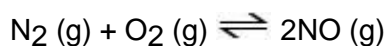
- A. Be—F, Mg—F, N—F, O—F
- B. O—F, N—F, Be—F, Mg—F
- C. O—F, Be—F, Mg—F, N—F
- D. N—F, Be—F, Mg—F, O—F
- E. Mg—F, Be—F, N—F, O—F

12. There are _____ paired and _____ unpaired electrons in the Lewis symbol for a fluorine atom.

- A. 4, 2
- B. 4, 1
- C. 6, 1
- D. 0, 5
- E. 2, 5

13. The basis of the VSEPR model of molecular bonding is _____.
- A. regions of electron density on an atom will organize themselves so as to maximize s-character
 - B. regions of electron density in the valence shell of an atom will arrange themselves so as to maximize overlap
 - C. atomic orbitals of the bonding atoms must overlap for a bond to form
 - D. electron domains in the valence shell of an atom will arrange themselves so as to minimize repulsions
 - E. hybrid orbitals will form as necessary to, as closely as possible, achieve spherical symmetry
14. An electron domain consists of _____.
- a) a nonbonding pair of electrons
 - b) a single bond
 - c) a multiple bond
- A. a only
 - B. b only
 - C. c only
 - D. a, b, and c
 - E. b and c
15. The molecular geometry of the PF₃ molecule is _____, and this molecule is _____.
- A. trigonal planar, polar
 - B. trigonal planar, nonpolar
 - C. trigonal pyramidal, polar
 - D. trigonal pyramidal, nonpolar
 - E. tetrahedral, unipolar
16. Of the following, _____ is a correct statement of Boyle's law.
- A. $PV = \text{constant}$
 - B. $\frac{P}{V} = \text{constant}$
 - C. $\frac{V}{P} = \text{constant}$
 - D. $\frac{V}{T} = \text{constant}$
 - E. $\frac{n}{P} = \text{constant}$

17. "Isothermal" means _____.
- A. at constant pressure
 - B. at constant temperature
 - C. at variable temperature and pressure conditions
 - D. at ideal temperature and pressure conditions
 - E. that $\Delta H_{\text{rxn}} = 0$
18. Which of the following molecules has hydrogen bonding as its only intermolecular force?
- A. HCl
 - B. NH_3
 - C. H_2O
 - D. CH_3OH
 - E. None, all of the above exhibit dispersion forces
19. On a phase diagram, the melting point is the same as _____.
- A. the triple point
 - B. the critical point
 - C. the freezing point
 - D. the boiling point
 - E. the vapor-pressure curve
20. At equilibrium, _____.
- A. all chemical reactions have ceased
 - B. the rates of the forward and reverse reactions are equal
 - C. the rate constants of the forward and reverse reactions are equal
 - D. the value of the equilibrium constant is 1
 - E. the limiting reagent has been consumed
21. The equilibrium expression for K_p for the reaction below is _____.



- A. $\frac{(2P_{\text{O}_2})(2P_{\text{N}_2})}{2P_{\text{NO}}}$
- B. $\frac{(P_{\text{O}_2})(P_{\text{N}_2})}{2P_{\text{NO}}}$
- C. $\frac{(P_{\text{O}_2})(P_{\text{N}_2})}{P_{\text{NO}}}$
- D. $\frac{(2P_{\text{NO}})}{(2P_{\text{N}_2})(2P_{\text{O}_2})}$
- E. none of the above

-
22. According to the Arrhenius concept, an acid is a substance that _____.
- A. is capable of donating one or more H^+
 - B. causes an increase in the concentration of H^+ in aqueous solutions
 - C. can accept a pair of electrons to form a coordinate covalent bond
 - D. reacts with the solvent to form the cation formed by autoionization of that solvent
 - E. tastes bitter
23. Which of the following ions will act as a weak base in water?
- A. OH^-
 - B. Cl^-
 - C. NO_3^-
 - D. ClO^-
 - E. None of the above will act as a weak base in water
24. Which statement about hydrocarbons is false?
- A. The smallest alkane to have structural (constitutional) isomers has 4 carbon atoms.
 - B. Cyclic alkanes are structural isomers of alkenes.
 - C. Alkanes are more reactive than alkenes.
 - D. Alkanes can be produced by hydrogenating alkenes.
 - E. Alkenes can be polymerized
25. Which one of the following is not an alcohol?
- A. acetone
 - B. glycerol
 - C. ethanol
 - D. cholesterol
 - E. ethylene glycol
-

[25 x 2 = 50]

SECTION B

**ANSWER THIS SECTION IN THE ANSWER BOOK 1.
GIVE ALL NUMERICAL ANSWERS TO THE CORRECT NUMBER OF SIGNIFICANT
FIGURES AND WITH APPROPRIATE UNITS.**

QUESTION 1

- 1.1 Determining the density and using the density to determine volume and mass
- (a) Calculate the density of mercury if 1.00×10^2 g occupies a volume of 7.36 cm^3 (2)
(b) Calculate the volume of 65.0 g of liquid methanol (wood alcohol) if its density is 0.791 g/mL . (2)
(c) What is the mass in grams of a cube of gold (density = 19.32 g/cm^3) if the length of the cube is 2.00 cm? (3)
- 1.2. How many significant figures are in each of the following numbers (assume that each number is a measured quantity): (a) 4.003, (b) 6.023×10^{23} , (c) 5000? (3)
- 1.3 How many protons, neutrons, and electrons are in an atom of (a) ^{197}Au , (b) strontium-90? (6)
- 1.4 Naturally occurring chlorine is 75.78% ^{35}Cl (atomic mass 34.969 u) and 24.22% ^{37}Cl (atomic mass 36.966 u). Calculate the atomic weight of chlorine. (4)

[20]**QUESTION 2**

- 2.1 Balance these equations by providing the missing coefficients: (10)
- (a) $\text{Fe(s)} + \text{O}_2(\text{g}) \longrightarrow \text{Fe}_2\text{O}_3(\text{s})$
(b) $\text{Al(s)} + \text{HCl(aq)} \longrightarrow \text{AlCl}_3(\text{aq}) + \text{H}_2(\text{g})$
(c) $\text{CaCO}_3(\text{s}) + \text{HCl(aq)} \longrightarrow \text{CaCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O(l)}$
(d) $\text{CH}_4(\text{g}) + \text{Br}_2(\text{l}) \longrightarrow \text{CBr}_4(\text{s}) + \text{HBr(g)}$
(e) $\text{Na(s)} + \text{H}_2\text{O(l)} \longrightarrow \text{NaOH(aq)} + \text{H}_2(\text{g})$
- 2.2 Determine the oxidation number of sulfur in (a) H_2S , (b) S_8 , (c) SCl_2 , (d) Na_2SO_3 , (e) SO_4^{2-} . (5)

- 2.3 Write the net ionic equation for the precipitation reaction that occurs when aqueous solutions of calcium chloride and sodium carbonate are mixed. (5)

[20]

QUESTION 3

- 3.1 Calculate the energy of one photon of yellow light that has a wavelength of 589 nm. (5)
- 3.2 Properties of metals oxides:
- (a) Would you expect scandium oxide to be a solid, liquid, or gas at room temperature? (2)
- (b) Write the balanced chemical equation for the reaction of scandium oxide with nitric acid. (3)
- 3.3 Which is predicted to have the shorter sulphur–oxygen bonds, SO_3 or SO_3^{2-} ? (5)
- 3.4 Use the VSEPR model to predict the molecular geometry of (a) O_3 , (b) SnCl_3^- . (5)

[20]

QUESTION 4

- 4.1 An unknown gas composed of homonuclear diatomic molecules effuses at a rate that is 0.355 times the rate at which O_2 gas effuses at the same temperature. Calculate the molar mass of the unknown and identify it. (5)
- 4.2 Automobile air bags are inflated by nitrogen gas generated by the rapid decomposition of sodium azide, NaN_3 :
- $$2 \text{NaN}_3(\text{s}) \longrightarrow 2 \text{Na}(\text{s}) + 3 \text{N}_2(\text{g})$$
- If an air bag has a volume of 36 L and is to be filled with nitrogen gas at 116.5 kPa and 26 °C, how many grams of NaN_3 must be decomposed? (5)
- 4.3 Use the phase diagram for methane, CH_4 , shown in Figure below to answer the following questions.
- (a) What are the approximate temperature and pressure of the critical point? (2)
- (b) What are the approximate temperature and pressure of the triple point? (2)
- (c) Is methane a solid, liquid, or gas at 100 kPa and 0 °C? (2)

(d) If solid methane at 100 kPa is heated while the pressure is held constant, will it melt or sublime? (2)

(e) If methane at 100 kPa and 0 °C is compressed until a phase change occurs, in which state is the methane when the compression is complete? (2)

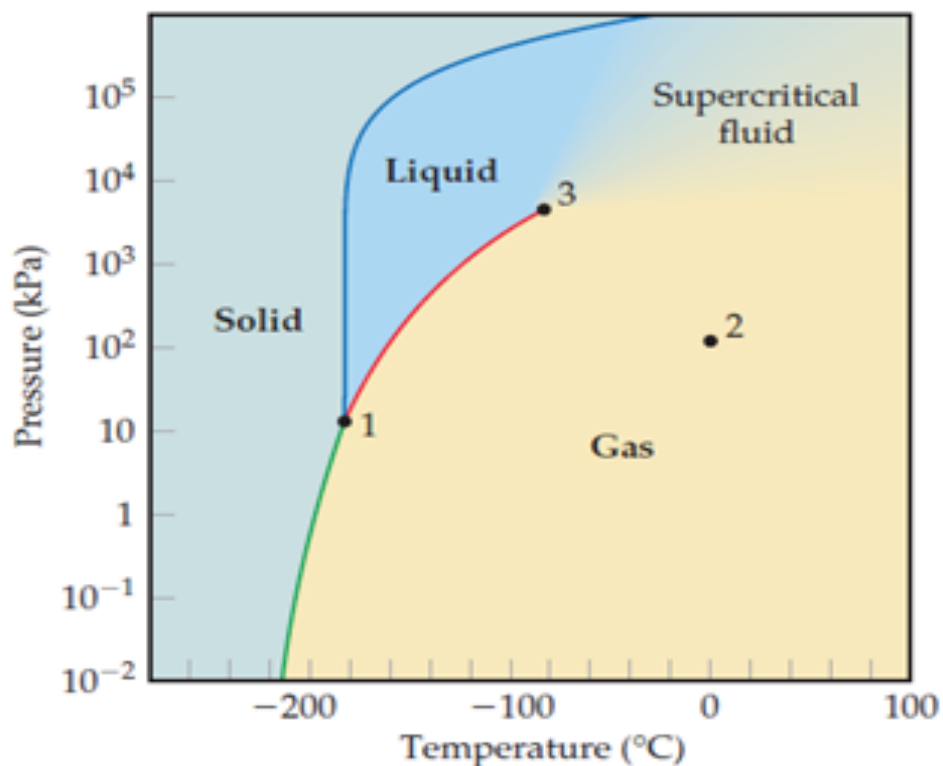
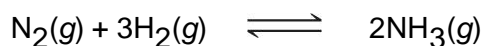


Figure 1 Phase diagram of CH₄. Note that a linear scale is used to represent temperature and a logarithmic scale to represent pressure.

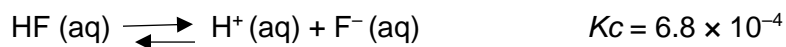
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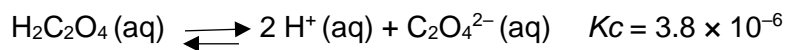
QUESTION 5

- 5.1 After a mixture of hydrogen and nitrogen gases in a reaction vessel is allowed to attain equilibrium at 472 °C, it is found to contain 747.8 kPa H₂, 249.3 kPa N₂, and 16.82 kPa NH₃. From these data, calculate the equilibrium constant K_p for the reaction (3)



- 5.2 Given the reactions





determine the value of K_c for the reaction (4)

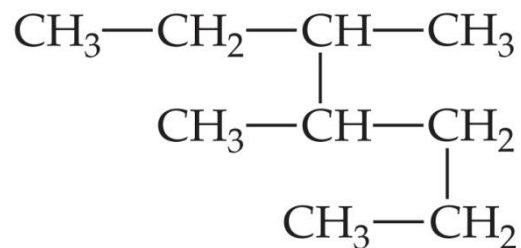


5.3 Identifying conjugates acids and bases

(a) What is the conjugate base of HClO_4 , H_2S , HCO_3^- ? (3)

(b) What is the conjugate acid of CN^- , SO_4^{2-} , H_2O , HCO_3^- ? (4)

5.4 Give the systematic name for the following alkane: (3)



5.5 Write the condensed structural formula for 3-ethyl-2-methylpentane. (3)

[20]

TOTAL MARKS [100]

Appendices

Constants:

Avogadro Number = 6.022×10^{23} / mole

Plank's Constant = 6.626×10^{-34} J-s

Speed of Light = 3.00×10^8 m/s

Faraday Constant = 96485 C/mol

Molar gas constant, $R = 8.314 \text{ m}^3\text{-Pa/mol-K} = 8.314 \text{ J/mol-K} = 0.08206 \text{ L-atm/mol-K}$

1 atm = 760. torr = 760. mm Hg = 101.325 kPa = 1.10325 bar

Equations:

1. Ideal gas equation: $PV = nRT$

2. Graham's Law: $\frac{r_x}{r_{\text{O}_2}} = \sqrt{\frac{\mathcal{M}_{\text{O}_2}}{\mathcal{M}_x}}$

3. Density: $d = MP/RT$

4. Molar mass: $M = mRT/PV$

Atomic Number

Department of Chemical Technology

1 H 1.0079	Atomic Number																2 He 4.0026
3 Li 6.941	4 Be 9.0122	Atomic Weight															
11 Na 22.990	12 Mg 24.305																
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.03	89 Ac 227.03															
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97				
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	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)				