UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

NATIONAL DIPLOMA: CHEMICAL ENGINEERING

MODULE CET1BP1
PHYSICAL CHEMISTRY 2

CAMPUS **DFC**

MAIN EXAMINATION

DATE: 07/11/2015 **SESSION: 08:30 – 11:30**

ASSESSORS **PROF P NGUNGU**
DR D NKOSI

INTERNAL MODERATOR **PROF OA AROTIBA**

EXTERNAL MODERATOR

DURATION 180 MINUTES **MARKS 150**

NUMBER OF PAGES: 10 PAGES, INCLUDING 1 ANNEXURE

INSTRUCTIONS: **ANSWER SECTION A (THE MULTIPLE CHOICE QUESTIONS) AND SECTION B (LONG QUESTIONS) IN THE ANSWER SCRIPT PROVIDED.**

FOR SECTION B, ANSWER QUESTION 1 AND 2 IN A SEPARATE ANSWER BOOK 1 AND QUESTIONS 3 AND 4 IN ANSWER BOOK 2.

CONSULT THE DATA SHEET AND THE PERIODIC TABLE FOR ALL SUPPLEMENTARY INFORMATION.

CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).

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

REQUIREMENTS: **2 ANSWER SCRIPT.**
MULTIPLE CHOICE ANSWER SHEET

SECTION A

1. Two aqueous solutions at room temperature are added to a calorimeter at the same time. The reaction between the two solutions results in the temperature of the solution to fall below room temperature. Which one of the following statements is **true**?

A. Energy is leaving the system during the reaction.
B. The reaction between the two solutions is endothermic.
C. The reaction between the two solutions is exothermic.
D. The change in temperature is meaningless since there are no gases produced.
E. Each statement is correct.

2. Which of the following statements is **not** part of the kinetic-molecular theory of gases?.

A. Gases consist of molecules in continuous, random motion.
B. The volume occupied by all of the gas molecules in a container is negligible compared to the volume of the container.
C. Attractive and repulsive forces between gas molecules are negligible.
D. The pressure of a gas increases when compressed at constant temperature.
E. The average kinetic energy of the molecules is proportional to the absolute temperature.

3. Which of the following equations is a valid statement of Charles' law?

A. PV = constant

B. V = constant x n

C. $\frac{V}{T}$ = constant

D. $\frac{P}{T}$ = constant

E. nT = constant

4. Which of the following statements about gases is **incorrect?**

A. Distances between molecules of gas are very large compared to bond distances within molecules.
B. Non-reacting gas mixtures are homogeneous.
C. All gases are colourless and odourless at room temperature.
D. Gases expand spontaneously to fill the container they are placed in.
E. Gases can be liquefied.

5. A glass vessel with a total pressure of 851 kPa contains He, Ne, and Ar. The partial pressures of He and Ne are 152 and 203 kPa, respectively, what is the mole fraction of Ar?

A. 0.583
B. 0.179
C. 0.238
D. 0.357
E. 0.851

/3…

6. A solution is made by dissolving 13.5 g of glucose ($C_6H_{12}O_6$) in 0.100 kg of water. Calculate the mass percentage of solute in this solution

A. 13.5 %
B. 11.9 %
C. 15.6 %
D. 10.0 %
E. 76.2 %

7. A 3.26 g sample of ground water was found to contain 7.5 µg of lead ions. What is the concentration of lead ions in ppm

A. 7.50
B. 3.26
C. 2.30
D. 4.35
E. 2.05

8. The normal boiling point of SO_2 is 263.1 K and that of NH_3 is 239.7 K. At –40 °C which of the following statements is **true**?

A. Ammonia has the greater vapour pressure.
B. Sulfur dioxide has the greater vapour pressure.
C. The vapour pressures would be equal.
D. The vapour pressure of NH_3 is 760 mmHg.
E The relative vapour pressures are not predictable from the data given.

9. Which one of the following statements is **incorrect**?

A. Most chemical reactions proceed faster if the concentration of one or more of the reactants is increased.
B. The rates of chemical reactions increase as the temperature is increased.
C. A first-order rection is one whose rate depends on the concentration of a single reactant raised to the first power.
D. The exponents in the rate law are always the same as the coefficients in the balanced chemical equation.
E. The rate constant is affected by the temperature and the catalyst.

10. Consider the combustion of ethylene (C_2H_2):

$$2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(l)$$

If the rate of appearance of CO_2 at a particular instant in a reaction vessel is 2.32×10^{-2} M.s^{-1}, what is the rate of disappearance of O_2?

A. 2.32×10^{-2} M.s^{-1}
B. 1.86×10^{-2} M.s^{-1}
C. 4.64×10^{-2} M.s^{-1}
D. 1.55×10^{-1} M.s^{-1}
E. 2.90×10^{-2} M.s^{-1}

11. A reaction $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ obeys the following rate law: Rate = $k[NO]^2[O_2]$. What are the units for the rate constant?

A. $M^{-1}.s^{-1}$
B. $M.s^{-1}$
C. $M^{-2}.s^{-1}$
D. M.s
E. $M^2.s^{-1}$

12. The decomposition of SO_2Cl_2 is a first order process:

$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$

The rate constant for the decomposition at 660 K is $4.50 \times 10^{-2}\ s^{-1}$. What is the half-life of SO_2Cl_2 in this reaction?

A. 59.3 seconds
B. 77.5 seconds
C. 46.5 seconds
D. 15.4 seconds
E. 17.7 seconds

13. A reaction A + B $\rightarrow$ C obeys the following rate law: Rate = $k[B]^2$. If the concentration of A was doubled, the rate would have…

A. increased by a factor of four.
B. stayed the same.
C. increased by a factor of two.
D. decreased by a factor of two.
E. decreased by a factor of four.

14. Which one of the following statements is **incorrect**?

A. The equilibrium constant of a reaction equation where the coefficients have been multiplied throughout by a number is the equilibrium constant raised to a power equal to that number.
B. Reducing the volume of a gaseous equilbrium mixture causes the system to shift in the direction that increases the number of moles of gas.
C. If a pure solid is involved in a heterogeneous equilibrium, its concentration is not included in the equilibrium-constant expression for the reaction.
D. The reaction quotient (Q) will equal the equilibrium constant (K_C) only if the system is at equilibrium.
E. A catalyst increases the rate at which equilibrium is achieved, but it does not change the composition of the equilibrium mixture.

15. One of the following is a way in which the value of the equilibrium constant, for a reaction in the gas phase, can be changed.

A. Adding a catalyst
B. Halving the pressure
C. Increasing the concentration of both reactants
D. Decreasing the temperature
E. Doubling the volume

16. Consider the following reaction at equilibrium at 135°C:

$B_2(g) + 3\ D_2(g) \rightleftharpoons 2\ BD_3(g)$

If 5.00 mol of $BD_3(g)$ were placed into a 25.0 dm^3 container and the concentration of $D_2(g)$ at equilibrium was 0.0150 $mol.dm^{-3}$, if the gas constant R is 8.20578×10^{-2} $L.atm.K^{-1}.mol^{-1}$, then the value of the equilibrium constant (K_p) is:

A. 2.14×10^6
B. 1.74×10^4
C. 2.40×10^9
D. 1.91×10^3
E. 8.20×10^{-2}

17. For the reaction $2AC(g) \rightleftharpoons 2A(g) + C_2(g)$, $K_c = 5.18 \times 10^{-5}$. What will happen when 9.44 mol of $AC(g)$, 0.452 mol of $A(g)$ and 0.452 mol $C_2(g)$ are added to a 20.0 dm^3 container and allowed to equilibrate?

A. The amount of A_2C will be halved.
B. More A_2C will be formed.
C. More A_2 will be formed than C_2.
D. More C_2 will be formed than A_2.
E. The amounts of A_2 and C_2 stay the same.

18. What is the pH of a 0.00125 $mol.dm^{-3}$ $Ca(OH)_2$?

A. 2.90
B. 11.4
C. 2.60
D. 11.1
E. 12.5

19. The molar solubility (in M) of AgCl, at 25°C, is

A. 1.3×10^{-5}
B. 1.7×10^{-5}
C. 4.2×10^{-5}
D. 4.6×10^{-5}
E 1.8×10^{-10}

[19 x 2 = 38]

SECTION B

ANSWER QUESTION 1 AND 2 IN A SEPARATE ANSWER BOOK 1 PROVIDED.

QUESTION 1

1.1 Using the following thermochemical equations:

$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta_rH° = -26.7\ kJ\ mol^{-1}$

$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$ $\Delta_rH° = -566.4\ kJ\ mol^{-1}$

Calculate the value of the enthalpy of reaction for the following reaction:

$4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$ (4)

1.2 When 10.02 g of liquid heptane (C_7H_{16}) is burned in the reaction vessel of a calorimeter, 1.50 L of water around the vessel increased its temperature from 20.0 °C to 85.0 °C. Ignoring the metallic material of the calorimeter, calculate the following:

1.2.1 The amount of heat generated per mole of heptane. (5)

1.2.2 Provide a balanced chemical equation for the combustion of heptane. (1)

1.2.3 The standard molar enthalpy of combustion of heptane, given the following information:

$\Delta_f H°$ of water = – 241.8 kJ/mol

$\Delta_f H°$ of carbon dioxide = – 393.5 kJ/mol

$\Delta_f H°$ of heptane = − 224.2 kJ/mol (4)

1.3 Provide two plausible reasons why the value calculated using the calorimeter is different from the value calculated using $\Delta_f H°$ values (2)

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QUESTION 2

2.1 Hot air balloons can rise when the air inside the balloon has a density that is 15.0% lower than the surrounding atmospheric air.

2.1.1 Given that the composition of dry air is mainly 78.09% nitrogen, 20.95% oxygen, and 0.93% argon, calculate the density of air at 301 K and 1.08×10^5 Pa (5)

2.1.2 Calculate the density of the air within the balloon when the balloon begins to rise. (1)

2.1.3 What is the temperature of the air inside the balloon? (3)

2.2 Sodium hydride reacts with excess water to produce aqueous sodium hydroxide and hydrogen gas:

$NaH(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$

At 28.0 °C and 102.3 kPa, calculate the mass of NaH needed to produce 982 mL of hydrogen gas. The hydrogen gas was collected over water, and the vapour pressure of water at this temperature is 36.5 kPa (7)

2.3 A biotechnologist isolates a gene fragment from a newly discovered bacterial strain, and dissolves 32.15 mg of the sample in enough water to make 65.8 mL of a solution. The osmotic pressure of the solution is then measured at 27.3 °C and found to be 0.431 torr.

2.3.1 What is the molar mass of the gene fragment? (10)

2.3.2 Calculate the freezing point depression for this solution, if the solution density is 0.997 g/mL and for pure water K_f = 1.86 °C/*m*.
$\Delta T_f = mK_f$ (7)

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QUESTION 3

ANSWER QUESTION 3 AND 4 IN A SEPARATE ANSWER BOOK 2.

3.1 Consider the following reaction:

$2A(aq) + 3X(aq) \rightarrow A_2X_3(aq)$

At a particular temperature, the molar concentration of substance X varies with time in the following manner:

Time (min)	[X] $mol.dm^{-3}$
0.00	0.400
3.00	0.200

What is the reaction rate (in $mol.dm^{-3}.s^{-1}$) for the consumption of substance A? (4)

3.2 Consider the following reaction:

$3A + 2B \rightarrow 2C + D$

At a particular temperature, the rate of this reaction varies with reactant concentrations in the following manner:

	Initial concentration (*M*)		
Experiment	A	B	Initial rate ($M.min^{-1}$)
1	1.00×10^{-2}	1.00×10^{-2}	6.00×10^{-3}
2	2.00×10^{-2}	3.00×10^{-2}	1.44×10^{-1}
3	1.00×10^{-2}	2.00×10^{-2}	1.20×10^{-2}

3.2.1 Determine the rate law for the reaction. Show all your calculations. (5)
3.2.2 Determine the rate constant for the reaction. (2)
3.2.3 If, in a volume of 2.00 dm^3, 0.15 moles of A and 0.060 moles of B were brought together, what will be the rate when 80.0 % of B has reacted? (7)

/8…

3.3 The rate constant for the decomposition of NO_2 is 0.835 s^{-1}:

$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$

3.3.1 Suppose a reaction is started with 0.0462 mol of NO_2 in a volume of 645 cm^3. How many seconds will the reaction take for the moles of NO_2 to drop by 85.6%? (5)

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QUESTION 4

4.1 Given the following **unbalanced** reaction equation at 2000°C:

$NO(g) \rightleftharpoons N_2(g) + O_2(g) \qquad K_C = 4.20$

4.1.1 Write the balanced equation. (1)

4.1.2 If 2.00 mol NO, 0.344 mol N_2 and 0.344 mol O_2 were placed in a 1.0 dm^3 container and the reaction was allowed to reach equilibrium, calculate the equilibrium concentrations of all the species. (8)

4.1.3 If temperature is kept constant and the volume were halved, how many moles of each gas would be present at the second equilibrium? (8)

4.2 Calculate the pH for each of the following solutions:

4.2.1 100.0 cm^3 of 0.0120 $mol.dm^{-3}$ of sodium benzoate (NaC_6H_5COO) ([K_a (C_6H_5COOH) = 6.00×10^{-5}]). (6)

4.2.2 a mixture of 100.0 mL of 0.0120 M KOH and 150.0 mL of 0.0550 M benzoic acid, C_6H_5COOH. [K_a (C_6H_5COOH) = 6.00×10^{-5}] (8)

4.3 What mass of ammonium chloride must be added to 100 mL of a 0.1500 *M* ammonia solution and diluted to 250 mL with water to produce a buffer of pH 9.30? K_b (Ammonia, NH_3) = 1.80×10^{-5} (6)

4.4 Silver ions ions are slowly added to a solution that contains 0.00150 *M* chloride ions and 0.0250 *M* bromide ions. Determine, by calculations, which anion will precipitate first.
K_{sp} (Silver chloride, AgCl) = 1.80×10^{-10},
K_{sp} (Silver bromide, AgBr) = 5.00×10^{-13} (6)

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DATA

Avogadro's number: $N = 6.02 \times 10^{23}$

$0^oC = 273.15$ K

Standard pressure = 1 atm = 101.325 kPa = 760 mmHg = 760 torr = 1.01325 bar

$R = 8.31451$ L.kPa .K^{-1}.mol^{-1}
$= 8.31451$ J.K^{-1}.mol^{-1}
$= 8.31451 \times 10^{-2}$ L.bar .K^{-1}.mol^{-1}
$= 8.20578 \times 10^{-2}$ L.atm .K^{-1}.mol^{-1}
$= 62.364$ L.torr .K^{-1}.mol^{-1}

$F = 9.6485 \times 10^4$ C.mol^{-1}

V = J.C^{-1}

UNIVERSITY OF JOHANNESBURG

Department of Applied Chemistry

Atomic Number

2 **He** *4.0026*

Atomic Weight

1 **H** *1.0079*																	2 **He** *4.0026*
3 **Li** *6.941*	4 **Be** *9.0122*											5 **B** *10.811*	6 **C** *12.011*	7 **N** *14.007*	8 **O** *15.999*	9 **F** *18.998*	10 **Ne** *20.179*
11 **Na** *22.990*	12 **Mg** *24.305*											13 **Al** *26.982*	14 **Si** *28.086*	15 **P** *30.974*	16 **S** *32.064*	17 **Cl** *35.453*	18 **Ar** *39.948*
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** *(234)*	96 **Cm** *(247)*	97 **Bk** *247*	98 **Cf** *(251)*	99 **Es** *(252)*	100 **Fm** *(257)*	101 **Md** *(258)*	102 **No** *(259)*	103 **Lr** *(260)*