OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA
DEPARTMENT OF CHEMISTRY
B.Sc. Degree (Chemistry) Examination Part II
CHM 203: Basic Physical Chemistry
Harmattan Mid-Semester Examination 2022/2023 Session

Instructions
Attempt all questions.

Time Allowed: 1 Hour
Date: 26th January, 2024

TYPE 4

1. At standard temperature and pressure, which of the following gases would you expect to have the least value of root-mean-square velocity: CO_2, CH_4, C_2H_6 or C_3H_8 [H = 1.008 g/mol; C = 12.01 g/mol; O = 16.00 g/mol; at STP, T = 273 K, P = 760 torr, Volume = 22.414 L mol^{-1}]

A. CO_2 B. CH_4
C. C_2H_6 D. C_3H_8

2. Given that the root-mean-square velocity, v_{rms} for $N_2(g)$ at 227°C is 667 m/s, determine the most probable velocity, v_{mp} and the average velocity, $\bar{v}$ for the gas at the same temperature; and hence arrange the three velocities in an increasing order of values. [N_2 = 28 g/mol; R = 8.314 J mol^{-1} K^{-1}].

A. v_{mp} = 615 m/s, $\bar{v}$ = 545 m/s; $\bar{v} > v_{mp} > v_{rms}$
B. v_{mp} = 545 m/s, $\bar{v}$ = 615 m/s; $v_{mp} < \bar{v} < v_{rms}$
C. v_{mp} = 615 m/s, $\bar{v}$ = 545 m/s; $\bar{v} < v_{mp} < v_{rms}$
D. v_{mp} = 545 m/s, $\bar{v}$ = 615 m/s; $v_{mp} > \bar{v} > v_{rms}$

3. Given that 2.75 moles of an ideal gas occupy 4.70 L at 53°C, calculate the pressure of the gas. R = 0.082 L. atm/K.mol.

A. 2.54 atm B. 15.7 atm
C. 73.5 atm D. 14.8 atm

4. The temperature in the stratosphere is –23°C. Calculate the root-mean-square speed of O_3 in this region

A. 260 m/s B. 441 m/s
C. 139 m/s D. 129 m/s

5. The molecular diameter of a gas and its number density are approximately 4 Å and 2.689 x 10^{19} molecules.cm^{-3} respectively at 0 °C and 1 atmosphere. Calculate the mean-free-path of the molecule of the gas [*1 Å = 10^{-10} m; π = 3.142*].

A. 9.28 × 10^{-6} cm B. 5.24 × 10^{2} cm
C. 9.28 × 10^{2} cm D. 5.24 × 10^{-6} cm

6. Which of the following statements is correct?

A. Heat is produced by the collision of gas molecules against one another
B. When a gas is heated, the molecules collide with one another more often
C. All gases obey the ideal gas law at all conditions
D. Average kinetic energy of a gas is independent of temperature

7. Under what set of conditions would a gas be expected to behave most ideally?

A. high temperature and low pressure
B. high temperature and high pressure
C. low temperature and high pressure
D. low temperature and low pressure

8. Given the constants, **a** as 3.59 atm. L^2/mol^2 and **b** as 0.0427 L/mol, calculate the pressure exerted by 2.50 moles of CO_2 confined in a volume of 5.00 L at 450 K. R = 0.082 atm. L/K. mol

A. 18.45 atm B. 14.37 atm
C. 17.96 atm D. 18.49 atm

9. When heat is added to a substance, its temperature rises. How much the temperature rises depends on the following, except

A. the source of the heat
B. the amount of heat added

C. the amount of substance present
D. the chemical nature and physical state of the substance

10. The heat capacity at constant-pressure, C_p of argon at room temperature is 20.8 J/K.mol. Given that the gas constant is 8.3 J/mol.K, calculate the heat capacity at constant-volume, C_v of argon.

A. 12.5 J/K.mol B. 33.3 J/K.mol
C. 41.6 J/K.mol D. 4.2 J/K.mol

11. Which statement best describes the variation of the rate constant of a reaction with temperature?

A. The rate constant does not change with temperature because it is an unvarying characteristic of the specific reaction.
B. The rate constant typically decreases with increasing temperature because fewer molecules are able to adopt the required orientation at higher temperature.
C. The rate constant typically increases with increasing temperature because increasing the temperature increases the fraction of collisions that result in reaction.
D. The rate constant typically increases with increasing temperature because most reactions become more favourable as the temperature increases.

12. Dichromate ion is reduced by chloride ion according to the equation below. If $[Cl^-]$ is decreasing at a rate of 0.37 mol L^{-1} min^{-1}, how is the concentration of $Cr^{3+}_{(aq)}$ changing?

$14\ H^+(aq) + Cr_2O_7^{2-}(aq) + 6\ Cl^-(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ Cl_2(g) + 7\ H_2O(l)$

A. Increasing by 0.12 mol L^{-1} min^{-1}
B. Increasing by 1.11 mol L^{-1} min^{-1}
C. Decreasing by 0.12 mol L^{-1} min^{-1}
D. Decreasing by 1.11 mol L^{-1} min^{-1}

13. The rate of the gas-phase reaction of nitrogen dioxide with carbon monoxide at 177 °C was measured under three different sets of concentrations as shown. What is the rate law for this reaction under these conditions?

$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$

	Initial $[NO_2]$, mol L^{-1}	Initial $[CO]$, mol L^{-1}	Initial rate, mol L^{-1} min^{-1}
Ex 1	4.0×10^{-4}	1.7×10^{-2}	1.70×10^{-7}
Ex 2	4.0×10^{-4}	3.4×10^{-2}	1.70×10^{-7}
Ex 3	1.2×10^{-3}	3.4×10^{-2}	1.53×10^{-6}

A. Rate = $k[NO_2]$
B. Rate = $k[NO_2]^2$
C. Rate = $k[CO]$
D. Rate = $k[NO_2][CO]$

14. Nitrogen dioxide reacts with carbon monoxide with the rate law shown

$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$
Rate = $k[NO_2]$

Which mechanisms are consistent with this rate law?

I. $2\ NO_2 \rightleftarrows N_2O_4$ *fast, unfavourable*
$N_2O_4 + CO \rightarrow N_2O_3 + CO_2$ *slow*

II. $N_2O_3 \rightarrow NO + NO_2$ *fast*
$2\ NO_2 \rightarrow NO + NO_3$ *slow*
$NO_3 + CO \rightarrow NO_2 + CO_2$ *fast*

A. I only
B. II only
C. Both I and II
D. Neither I nor II

15. Which statement about catalysis is correct?

A. If a catalyst increases the forward rate of a reaction by a factor of two, it must increase the rate of the reverse reaction by a factor of two
B. If a catalyst increases the rate of formation of a product by a factor of two, it must increase the rate of formation of the mirror image of the product by a factor of two
C. A catalyst must be in the same phase as the reactants and products of the reaction
D. A catalysed reaction must proceed by the same mechanism as the uncatalyzed reaction, but with a lower activation energy.

16. A quantity of 1.274 g of naphthalene ($C_{10}H_8$; molar mass = 128.2 g/mol), a pungent smelling substance used in moth repellants, was burned in a constant-volume bomb calorimeter. Consequently, the temperature of the water rose from 21.49°C to 26.52°C. If the heat capacity of the bomb plus water was 10.17 kJ/°C, calculate the molar heat of combustion of naphthalene.

A. –5148 kJ/mol B. –0.5083 kJ/mol
C. –508.4 kJ/mol D. –51.16 kJ/mol

17. A quantity of 1.922 g of methanol (CH_3OH; molar mass = 32.042 g/mol) was burned in a constant-volume bomb calorimeter. Consequently, the temperature of the water rose by 4.20°C. If the molar heat of combustion of methanol is -728 kJ/mol, calculate the heat capacity of the bomb plus water.

A. 173 kJ/°C B. 10.4 kJ/°C
C. 2889.7 kJ/°C D. 17.3 kJ/°C

18. The molar heat capacity of xenon at constant-pressure, C_p is given as 20.79 J/K.mol. Assuming that C_p is independent of temperature, calculate the value of enthalpy change, ΔH for the heating of 55.4 g of xenon from 300 K to 400 K. Molar mass of xenon is 131.29 g/mol.

A. 2079 J B. 4927 J C. 877 J D. 422 J

19. An increase in temperature tends to
A. favour product formation for endothermic reactions
B. have no effect on either endothermic or exothermic reactions
C. favour product formation for exothermic reactions
D. favour reactant formation for endothermic reactions

20. which of the following statements is false
A. an isolated system exchanges neither energy nor matter with its surroundings
B. Extensive variables depends on the amount of substance present in the system
C. the value of intensive parameters can be measured at any point within the system
D. for a constant-pressure process, the heat absorbed by the system, $q_p = \Delta U$

21. Which of the following is a state function and also an extensive variable?
A. Internal energy
B. Pressure
C. Molar heat capacity
D. Temperature

22. The total sum of series of changes in a thermodynamic state variable, δ can be expressed as $\oint \delta$. Which of the following statements is true?
A. $\oint \delta = 0$ for an irreversible process
B. $\oint \delta = 0$ for a cyclic process
C. $\oint \delta = 0$ for a non-cyclic process
D. $\oint \delta = 0$ for all thermodynamic processes

23. Consider the following comments on a thermodynamic system:
I. The first law of thermodynamic doesn't predict spontaneity or otherwise of a process.
II. $\Delta U = 0$ for an isothermal process
III. $\Delta U = -w$ for an adiabatic process
IV. $\Delta U = q$ for an isobaric process
Which of the following combinations of I – IV can be considered to be true?
A. I, II and IV only B. I, II, III and IV
C. I, III, and IV only D. I, II and III only

24. If a system absorbs 20 kJ heat and does 15 kJ of work, its internal energy would
A. Decrease by 20 kJ B. Increase by 5 kJ
C. Decrease by 5 kJ D. Increase by 25 kJ

25. An ideal gas expands isothermally and reversibly until its volume is 100 times its initial volume. If the process involves 0.1 mole of the gas at 1000 K, the work done can be expressed as ($R = 8.314\ J\ mol^{-1}\ K^{-1}$)
A. $-1663In(10)\ kJ$

B. $-831.4ln(10)\ kJ$
C. $-1.663ln(10)\ kJ$
D. $-831.4ln(10)\ J$

26. A substance P decomposes irreversibly to form Q. A plot of ln([P]) as a function of time from the beginning of the reaction until Q is 97% consumed is a straight line with a negative slope. What is the reaction order in P?

A. Zero order
B. First order
C. Second order
D. Third order

27. Sulfuryl chloride (SO2Cl2) decomposes via first-order kinetics. The half-life is 4.1 minutes at a certain temperature. How long does it take for 30% of the SO2Cl2 in a sample to decompose at this temperature?

A. 0.6 min
B. 2.1 min
C. 2.5 min
D. 7.1 min

$t_{1/2} = \frac{\ln 2}{k}$ $\quad k = 0.1691$

$4.1 = \frac{\ln 2}{k}$ $\quad \ln(0.7) = -0.1691t$

$k = \frac{\ln 2}{4.1}$

28. The rate constant of a chemical reaction increases 26% when the temperature is raised from 50 °C to 55 °C. What is the activation energy of this reaction?

A. 1.1 kJ mol^{-1}
B. 18 kJ mol^{-1}
C. 41 kJ mol^{-1}
D. 220 kJ mol^{-1}

$\ln\left(\frac{1.26}{1}\right) = \frac{Ea}{8.314}\left(\frac{5}{\quad}\right)$

$0.23111 =$

$A_0 = 1$

$A_t = 0.26A_0 + A_0$

$= 1.26$

29. In the reaction

$Cl_{2(g)} + 3\ F_{2(g)} \rightarrow 2\ ClF_{3(g)}$

the rate of disappearance of $F_{2(g)}$ is 1.0 M s^{-1}. What is the rate of appearance of $ClF_{3(g)}$?

A. 0.33 M s^{-1}
B. 0.67 M s^{-1}
C. 1.00 M s^{-1}
D. 1.50 M s^{-1}

$\frac{1}{3} \times 1 = \frac{1}{2} Rate$

30. The rate constant for an elementary chemical reaction can be affected by which of the following?

I. Reactant concentrations
II. Product concentrations
A. I only
B. II only
C. Both I and II
D. Neither I nor II