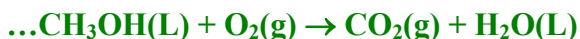


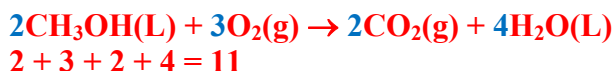
**CHEM 101+103 FIRST SEMISTER 1431-1432H
FINAL EXAM SOLUTINS**

1. When the following equation is balanced, the sum of the smallest set of whole numbers coefficient is:



- A) 15 B) 13 C) 11 D) 10

SOLUTION



2. How many moles of Freon, CF_2Cl_2 , are there in 363 g of CF_2Cl_2 ?

- A) 3.0 B) 3.5 C) 4.0 D) 4.5

SOLUTION

$$n = \frac{m}{M} = \frac{363}{120.9} = 3 \text{ mol}$$

3. How many grams of sodium chloride, NaCl , are there in 100 ml of 1.54 M aqueous solution of NaCl ?

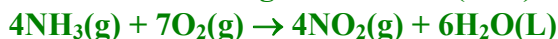
- A) 7.0 B) 9.0 C) 11.0 D) 12.0

SOLUTION

$$n = C \times V = 1.54 \times 0.1 = 0.154 \text{ mol}$$

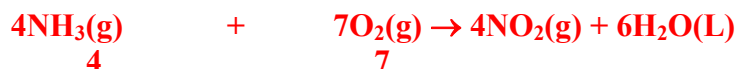
$$m = n \times M = 0.154 \times 58.45 = 9 \text{ g}$$

4. According to the following equation, how many grams of oxygen (O_2) are consumed in the combustion of 30.42 g of ammonia (NH_3) according to ?



- A) 90.0 B) 95.0 C) 100.0 D) 105.0

SOLUTION



$$\frac{m}{M} = \frac{30.42}{17} = 1.79 \text{ mol}$$

$$n = \frac{1.79 \times 7}{4} = 3.13 \text{ mol}, m = n \times M = 3.13 \times 32 = 100 \text{ g}$$

5. A mixture of three gases Ar, Kr and Xe has a total pressure of 6.70 atm. What is the mole fraction of Kr if the partial pressure of Xe is 1.60 atm and the partial pressure of Ar is 2.80 atm ?

- A) 0.296 B) 0.343 C) 0.395 D) 0.422

SOLUTION

$$P_{\text{Kr}} = P_t - P_{\text{Ar}} - P_{\text{Xe}} = 6.7 - 2.8 - 1.6 = 2.3 \text{ atm}$$

$$X_{\text{Kr}} = \frac{P_{\text{Kr}}}{P_t} = \frac{2.3}{6.7} = 0.343$$

6. Which one of the following gases will have the greatest rate of effusion at the same temperature ?

- A) Ne B) NH₃ C) CH₄ D) NO

SOLUTION

$M_{\text{Ne}} = 20.18 \text{ g/mol}$, $M_{\text{NH}_3} = 17 \text{ g/mol}$, $M_{\text{CH}_4} = 16 \text{ g/mol}$, $M_{\text{NO}} = 28 \text{ g/mol}$
CH₄ has the greatest rate of effusion

7. According to the Kinetic-Molecular theory of gases, which of the following statements *is true* for the molecules of hydrogen gas H₂ and those of helium gas, He, at the same temperature:

- A) The molecules of H₂ and those of He will have the same average kinetic energy.
B) The average kinetic energy of He molecules is about 4-times greater than that of the H₂ molecules.
C) The average kinetic energy of He molecules is about 2-times greater than that of the H₂ molecules.
D) The average kinetic energy of H₂ molecules is about 4-times greater than that of the He molecules.

SOLUTION

At the same temperature, the kinetic energy is the same for any gas molecule.

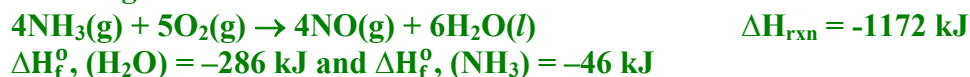
8. The Van der Waals equation corrects the ideal gas law for the finite:

- A) Volume, pressure and temperature.
B) Volume and temperature only.
C) Pressure and temperature only.
D) Volume and pressure only.

SOLUTION

The ideal law is $PV = nRT$, while van der Waals equation is $(P + a \frac{n^2}{V^2})(V - bn) = nRT$. Therefore it corrects the ideal gas law for the finite P and V.

9. Find the standard enthalpy of formation ΔH_f° of NO gas (in kJ), given the following data



- A) -85 B) +85 C) -105 D) +90

SOLUTION

$\Delta H_{\text{rxn}} = \sum \Delta H_f^\circ, (\text{p}) + \sum \Delta H_f^\circ, (\text{r})$
 $-1172 = (4 \times \Delta H_f^\circ, (\text{NO}) + 6 \times -286) - (4 \times -46 + 5 \times 0)$
 $\Delta H_f^\circ, (\text{NO}) = +90 \text{ kJ/mol}$

10. The internal energy ΔE (ΔU) of the system is always negative if the system:

- A) Absorbs heat and does work.
- B) Gives off heat and does work.
- C) Gives off heat and has work done on it.
- D) Absorbs heat and has work done on it.

SOLUTION

According to the first law equation ($\Delta E = q + w$), ΔE is always negative if both q and w are negative. i.e. if the system gives off heat and does work.

11. The vapor pressure of pure water at 25°C is 23.8 torr. What is the vapor pressure (in torr) of water above an aqueous solution of 500 g glucose $C_6H_{12}O_6$ (a nonelectrolyte) in 500 g of water.
- A) 21.64 B) 22.15 C) 22.75 D) 23.42

SOLUTION

$$X_1 = \frac{n_1}{n_1 + n_2} = \frac{\frac{m_1}{M_1}}{\frac{m_1}{M_1} + \frac{m_2}{M_2}} = \frac{\frac{500}{18}}{\frac{500}{18} + \frac{500}{180}} = 0.909, \quad P_1 = X_1 P_1^0 = 0.909 \times 23.8 = 21.64 \text{ torr}$$

- 12 What is the molar mass (in g/mole) of nicotine (a nonelectrolyte) if 12 mL aqueous solution containing 0.6 g of nicotine has an osmotic pressure of 7.55 atm at 25°C ?

- A) 162 B) 218 C) 275 D) 474

SOLUTION

$$\square V = nRT, \quad \square = \frac{n}{V} RT = \frac{m}{M} RT, \quad M = \frac{mRT}{V} = \frac{0.6 \times 0.0821 \times 298}{7.55 \times 0.012} = 162 \text{ g/mol}$$

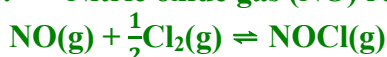
13. Three separate 250.0 mL aqueous solutions, the first contains 100.0 g of urea $CO(NH_2)_2$, the second contains 100.0 g of glucose $C_6H_{12}O_6$ and the third contains 100.0 g of sucrose $C_{12}H_{22}O_{11}$ (all of the three solutes are nonelectrolytes). Which of the following is a true statement ?

- A) All the three solutions should have the same boiling point.
- B) The sucrose solution should have the highest boiling point.
- C) The glucose solution should have the highest boiling point.
- D) The urea solution should have the highest boiling point.

SOLUTION

Because $n = \frac{m}{M}$ and all have the same masses, n will be higher for the one with the lowest M , which is urea. And because $\Delta T_b = K_b \times m$, and m is higher for the one with the highest n , ΔT_b will be higher for the one with the urea solution.

14. Nitric oxide gas (NO) reacts with chlorine gas (Cl_2) according to:



The following initial rates of reaction have been measured for the given concentrations:

Exp.	[NO] mol/L	[Cl ₂] mol/L	Initial rate (mol L ⁻¹ hr ⁻¹)
1	0.50	0.50	1.19
2	1.0	0.50	4.76

3	1.0	1	9.52
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Therefore, the units for the rate constant for this reaction must be:

- A) hr^{-1} B) $\text{mol}^{-1} \text{L hr}^{-1}$ C) $\text{mol}^2 \text{L}^2 \text{hr}^{-1}$ D) $\text{mol L}^{-1} \text{hr}^{-1}$

SOLUTION

$$\text{rate} = k [\text{NO}]^x [\text{Cl}_2]^y, k = \frac{\text{rate}}{[\text{NO}]^x [\text{Cl}_2]^y}, k \text{ UNITS} = \frac{\text{rate units}}{\{\text{units of } [\text{NO}]\}^x \{\text{units of } [\text{Cl}_2]\}^y}$$

$$\frac{\text{rate}_2}{\text{rate}_1} = \frac{4.76}{1.19} = \frac{k[1]^x [0.5]^y}{k[0.5]^x [0.5]^y}, 4 = 2^x, X = 2$$

$$\frac{\text{rate}_3}{\text{rate}_2} = \frac{9.52}{4.76} = \frac{k[1]^x [1]^y}{k[1]^x [0.5]^y}, 2 = 2^y, y = 1$$

$$\text{reaction order (n)} = 2 + 1 = 3$$

$$k \text{ UNITS} = \text{mol}^{1-n} \text{L}^{n-1} \text{hr}^{-1} = \text{mol}^{1-3} \text{L}^{3-1} \text{hr}^{-1} = \text{mol}^2 \text{L}^{-2} \text{hr}^{-1}$$

15. If the activation energy for a first order reaction is 184.0 kJ/mol, by what factor will the rate constant of this reaction increase when the reaction temperature increases from 500°C to 520°C?

- A) 2.0 B) 2.5 C) 4.0 D) 5.5

SOLUTION

$$\ln \frac{k_2}{k_1} = \frac{184}{8.314 \times 10^{-3}} \frac{793 - 773}{793 \times 773} = 0.72, \frac{k_2}{k_1} = 2, k_2 = 2 \times k_1$$

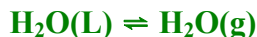
16. Which of the following is a true statement about chemical equilibrium in general?

- A) At equilibrium, the total concentration of products must be equal to the total concentration of reactants.
 B) Equilibrium is the result of cession (stoppage) of all chemical change.
 C) The rate constant of the forward reaction must be equal to the rate constant of the reverse reaction.
 D) At equilibrium, the rate of the forward process is the same as the rate of the reverse process.

SOLUTION

Chemical equilibrium is established when the two oppsie reactions are at equal rate. It is dynamic, i.e. it does not stop, the concentrations are not necessarily equal, and the two reactions' rate constants are different.

17. What is the K_c value for the following equilibrium occurring at 27°C ?



(Given the vapor pressure of water at 27°C is 30.0 mmHg)

- A) 7.2×10^{-3} B) 4.4×10^{-3} C) 1.6×10^{-3} D) 1.2×10^{-4}

SOLUTION

$$K_p = P_{\text{H}_2\text{O}} = \frac{30}{760} = 0.039$$

$$K_c = K_p (\text{RT})^{-\Delta n_g} = 0.039 (0.0821 \times 300)^{-1} = 1.59 \times 10^{-3}$$

OR

$$\frac{n}{v} = \frac{P}{\text{RT}}, [\text{H}_2\text{O}(\text{g})] = \frac{P}{\text{RT}} = \frac{0.039}{0.0821 \times 300} = 1.59 \times 10^{-3}, K_c = [\text{H}_2\text{O}(\text{g})] = 1.59 \times 10^{-3}$$

18. The following reaction was allowed to come to equilibrium at 700°C:



The initial amounts of reactants placed into 5.0 L vessel were 4.0 moles of SO_2 and 3.0 moles of O_2 . After the reaction reached equilibrium, 3.5 moles of SO_2 were found. Calculate the value of K_c for this reaction.

- A) 3.71×10^{-2} B) 7.64×10^{-2} C) 9.56×10^{-2} D) 1.68×10^{-3}

SOLUTION

$2\text{SO}_2(\text{g})$	+	$\text{O}_2(\text{g})$	\rightleftharpoons	$2\text{SO}_3(\text{g})$
$-2X$		$-X$		$+2X$
$\frac{4}{5} = 0.8$		$\frac{3}{5} = 0.6$		0

$[\text{SO}_2]_{\text{equil}} = \frac{3.5}{5} = 0.7 \text{ molar}$
 $0.7 = 0.8 - 2X, X = \frac{0.8 - 0.7}{2} = 0.05$
 $[\text{O}_2]_{\text{equil}} = 0.6 - X = 0.6 - 0.05 = 0.55 \text{ molar}$
 $[\text{SO}_3]_{\text{equil}} = 0 + 2X = 2 \cdot 0.05 = 0.1 \text{ molar}$
 $K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = \frac{0.1^2}{0.7^2 \times 0.55} = 0.0371 = 3.71 \times 10^{-2}$

19. 100 g of solid ammonium hydrogen sulfide (NH_4HS) was introduced into an empty 1.0 L reaction vessel. The closed vessel was heated to 300°C, and the following reaction came to equilibrium:



At equilibrium, the total pressure inside the reaction vessel was 0.9 atm. Calculate the value of K_p for this reaction.

- A) 0.81 B) 0.90 C) 0.20 D) 0.45

SOLUTION

$\text{NH}_4\text{HS}(\text{s})$	\rightleftharpoons	$\text{NH}_3(\text{g})$	+	$\text{H}_2\text{S}(\text{g})$
		$+X$		$+X$

$P_{\text{NH}_3} = P_{\text{H}_2\text{S}} = \frac{0.9}{2} = 0.45 \text{ atm}$
 $K_p = P_{\text{NH}_3} \times P_{\text{H}_2\text{S}} = 0.45^2 = 0.2$

20. Under certain conditions of temperature and pressure, the following reaction has an equilibrium constant $K_c = 0.8$



At a certain moment, the following amounts of reactants are present in the 2.5 L reaction vessel:

5.0 moles of hydrogen gas, 7.5 moles of solid sulfur and 4.0 moles of hydrogen sulfide gas.

At this moment, is the mixture at equilibrium? If not at equilibrium, which response is correct ?

- A) Yes, the mixture is at equilibrium.
 B) No, the mixture must occur from left to right (go forward) to reach equilibrium.

C) No, the reaction must occur from right to left (go backward) to reach equilibrium.

D) No, a proper catalyst is needed to achieve equilibrium.

SOLUTION

$$[\text{H}_2\text{S}] = \frac{n}{v} = \frac{4}{2.5} = 1.6 \text{ M}, [\text{H}_2] = \frac{n}{v} = \frac{5}{2.5} = 2 \text{ M}$$

$$K_c = \frac{[\text{H}_2\text{S}]}{[\text{H}_2]} = \frac{1.6}{2} = 0.8, Q = 0.8$$

Because $K_c = Q$ the mixture is at equilibrium.

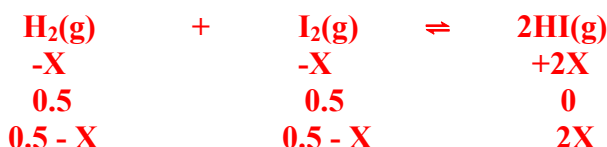
21. At 400°C, $K_c = 54.30$ for the equilibrium:



If 0.50 mol of H_2 and 0.50 mol of I_2 are introduced into an empty 1.0 L vessel and allowed to achieve equilibrium. Find the equilibrium concentration of HI at 400°C.

A) 0.428 M B) 0.555 M C) 0.648 M D) 0.787 M

SOLUTION



$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}, 54.3 = \frac{4X^2}{(0.5-X)^2}, 7.37 = \frac{2X}{0.5-X}, X = 0.393$$

$$[\text{HI}] = 2X = 2 \times 0.393 = 0.787 \text{ M}$$

22. Consider the following reaction at equilibrium:



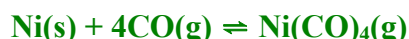
Which one of the following procedures could cause the SO_3 concentration to increase?

- A) Increase the temperature and increase the pressure.
- B) Increase the temperature and decrease the pressure.
- C) Decrease the temperature and increase the pressure.
- D) Decrease the temperature and decrease the pressure.

SOLUTION

According to Le Chatelier's principle, if the forward reaction is exothermic, decreasing the temperature will shift it to the direction that is exothermic (right), and increasing the pressure will shift it to the direction of producing smaller number of gaseous molecules (also right).

23. The equilibrium constant $K_c = 5.0 \times 10^4$ at 25°C for the following reaction:



What is the value of the equilibrium constant K_c at 25°C for the following equilibrium reaction?



A) 4.0×10^{-10} B) 2.5×10^{-10} C) 4.0×10^{-5} D) 2.5×10^{-5}

SOLUTION

Because the second equation is the equal to double the reverse of the first, its equilibrium constant is equal to squared the reverse of the first:

$$K_c = \frac{1}{(5.0 \times 10^4)^2} = 4 \times 10^{-10}$$

24. The pOH of a 1.2 M C₂H₅NH₂ (ethylamine), a weak base, is 1.59. Calculate the K_b value for this base.

A) 6.2×10⁻⁵ B) 5.5×10⁻⁴ C) 7.4×10⁻³ D) 4.2×10⁻³

SOLUTION

$$[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-1.59} = 0.0257, [\text{OH}^-] = \sqrt{K_b \times C_b}$$

$$0.0257 = \sqrt{K_a \times 1.2}$$

$$K_a = 5.5 \times 10^{-4}$$

25. Formic acid, HCOOH, is a monoprotic weak acid (K_a = 1.7 × 10⁻⁴). Calculate the hydrogen ion concentration, in M unit, in a 0.11 M of this acid.

A) 1.9×10⁻⁵ B) 5.3×10⁻⁴ C) 1.7×10⁻⁴ D) 4.3×10⁻³

SOLUTION

$$[\text{H}^+] = \sqrt{K_a \times C_a} = \sqrt{1.7 \times 10^{-4} \times 0.11} = 4.3 \times 10^{-3} \text{ M}$$

26. The hydrogen ion concentration [H⁺] in a solution is 2.51×10⁻⁴ M. calculate the pOH value of this solution.

A) 10.4 B) 9.8 C) 9.2 D) 8.8

SOLUTION

$$\text{pOH} = 14 - \text{pH} = 14 - (-\log [\text{H}^+]) = 14 - (-\log 2.51 \times 10^{-4}) = 10.40$$

27. For nitrous acid, HNO₂, K_a = 4.5×10⁻⁴. Calculate the K_b value for NO₂⁻.

A) 2.5×10⁻¹⁰ B) 4.5×10⁻¹⁰ C) 2.2×10⁻¹¹ D) 4.5×10⁻¹²

SOLUTION

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{4.5 \times 10^{-4}} = 2.22 \times 10^{-11}$$

28. Calculate the pH of a buffer solution prepared by dissolving 0.2 mol of cyanic acid (HCNO) and 0.8 mol of sodium cyanate (NaCNO) in enough water to make 1.0 liter of solution. (K_a HCNO = 2.0×10⁻⁴)

A) 3.6 B) 3.8 C) 4.1 D) 4.3

SOLUTION

$$\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]} = -\log 2.0 \times 10^{-4} + \log \frac{0.8}{0.2} = 4.3$$

29. The pH value of 2.5×10⁻³ M Ba(OH)₂, strong base, solution is:

A) 11.5 B) 11.7 C) 11.9 D) 12.1

SOLUTION

$$\text{pOH} = -\log [\text{OH}^-] = -\log (n \times C_a) = -\log (2 \times 2.5 \times 10^{-3}) = 2.3$$

$$\text{pH} = 14 - \text{pOH} = 14 - 2.3 = 11.7$$

30. The conjugated acid of the base (PO_4^{3-}) is:

- A) H_3PO_4 B) H_2PO_4^- C) HPO_4^{2-} D) HPO_3

SOLUTION

It is HPO_4^{2-} , because the conjugate acid is higher than its conjugate base by only one H^+ .