

CANADIAN CHEMISTRY CONTEST

CHEMISTRY

TOPIC QUESTIONS

King

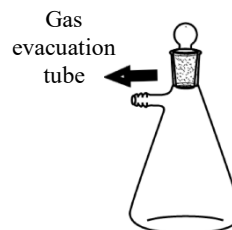


7. Equilibria



KingCh

- 6) Some air is evacuated from a 400.0 mL Erlenmeyer flask at 25.0°C. Assuming Ideal Gas Law behaviour, what is the partial pressure of O₂ inside the container if 1.21 x 10⁻² mol gas remain in the container, consisting of 9.44 x 10⁻³ mol N₂, 1.17 x 10⁻⁴ mol Ar and O₂ is the only other gas in the container?



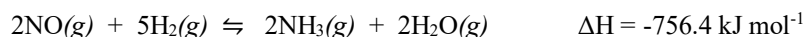
- A) 75.0 kPa B) 63.9 kPa C) 47.1 kPa D) 39.3 kPa E) 15.8 kPa

- 24) The K_{sp} value for SrSO₄ is 7.6×10^{-7} , and the K_{sp} value for SrF₂ is 7.9×10^{-10} . Sr(NO₃)₂(s) is added to 1.00 L of solution containing 0.020 mol F⁻ and 0.20 mol of SO₄⁻² with constant volume. Which salt **precipitates first**, and what is the [Sr²⁺] in solution when the precipitate forms?

- A) SrF₂ and SrSO₄ both precipitate when [Sr²⁺] = 3.8×10^{-4} mol L⁻¹
 B) SrF₂ precipitates first, when [Sr²⁺] = 2.0×10^{-6} mol L⁻¹
 C) SrF₂ precipitates first, when [Sr²⁺] = 1.6×10^{-7} mol L⁻¹
 D) SrSO₄ precipitates first, when [Sr²⁺] = 7.7×10^{-8} mol L⁻¹
 E) SrSO₄ precipitates first, when [Sr²⁺] = 5.3×10^{-9} mol L⁻¹

CCC 2021

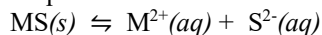
- 9) Consider the following equilibrium in a sealed container



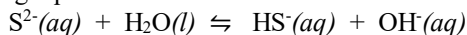
Which of the following changes would most likely shift the equilibrium position towards reactants?

- A) Increasing the temperature D) Adding nitrogen monoxide gas
 B) Adding argon gas E) Removing ammonia
 C) Decreasing the volume of the sealed container

- 24) Metal sulfides have considerable applications in industry, including their use as components of semiconducting materials. Consider the following equilibrium, where M represents a transition metal:



S^{2-} ions liberated in solution readily react and form HS^- and OH^- according to the following equilibrium:

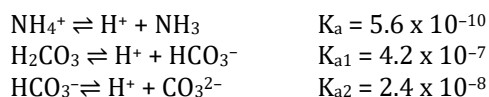


Which of the following will increase the solubility of the metal sulfide?

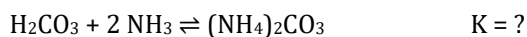
- A) Increasing the concentration of OH^- by adding a strong base
- B) Adding a strong acid
- C) Increasing the amount of the metal sulfide present
- D) Diluting the solution present
- E) Adding MCl_2

CCC 2020

- 18) Given the following set of equilibria and their respective constants



what would the equilibrium constant be for the reaction below?



- A) 1.8×10^{-5}
- B) 4.4×10^{-7}
- C) 9.0×10^{-6}
- D) 3.2×10^4
- E) 3.1×10^{-5}

- 23) For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2 HI(g)$ $\Delta H^\circ = +52.96 \text{ kJ}$. Which of the following statement(s) is/are correct?

- I. The heat of formation of 1 mol of HI is +26.48 kJ
- II. As the temperature increases, the reaction will proceed to the right
- III. As the pressure increases, the reaction will proceed to the right

- A) I only
- B) I and II only
- C) I, II and III
- D) II and III only
- E) III only

- 22) The equilibrium $CO(g) + NO_2(g) \rightleftharpoons CO_2(g) + NO(g)$ is established in four different, but identical containers. Each container started with a different composition as follows:

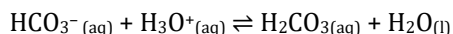
Container	CO (mol)	NO ₂ (mol)	CO ₂ (mol)	NO (mol)
1	1	1	0	0
2	1	0	1	1
3	1	1	1	0
4	0	1	1	1
5	1	1	1	1

After equilibrium is established, which container would have the largest concentration of CO (g)

- A) 1
- B) 2
- C) 3
- D) 4
- E) 5

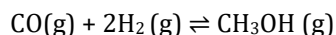
CCC 2019

12) Which of the following would increase the K_{eq} of the reaction below?



- A) Increasing the pH B) Decreasing the pH C) Adding water
 D) Adding H_2CO_3 E) None of the options provided

24) Over 80% of global methanol (CH_3OH) production is converted into further synthetic chemicals. Consequently, methanol is an economically significant chemical compound. *Methanex*, a Vancouver-based company, is the world's largest producer and distributor of methanol. Methanol is produced according to the following balanced chemical reaction:

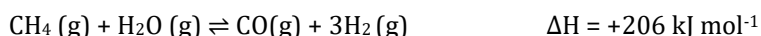


Given initial partial pressures of $P_{\text{CO}} = 26$ bar and $P_{\text{H}_2} = 65$ bar, and an equilibrium partial pressure of $P_{\text{CH}_3\text{OH}} = 16$ bar, determine K_p . Assume constant container volume and ideal gas behaviour.

- A) 1.5×10^{-4} B) 6.7×10^{-4} C) 1.5×10^{-3}
 D) 3.3×10^{-2} E) 4.8×10^{-2}

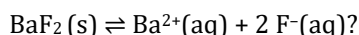
CCC 2018

9) Predict the conditions maximizing the rate of hydrogen gas production in the steam methane reforming reaction:



- A) Low temperature, high pressure and a catalyst
 B) Low temperature, low pressure and a catalyst
 C) Low temperature, high pressure and no catalyst
 D) High temperature, high pressure and a catalyst
 E) High temperature, low pressure and a catalyst

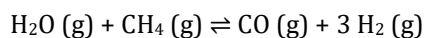
11) The following data were taken for the addition of solid barium fluoride to enough water to make 100.0 mL of solution. What is the K_{sp} of barium fluoride:



Mass of solid added (g)	Mass of solid dissolved (g)	Mass of solid undissolved (g)
0.100	0.100	0
0.200	0.200	0
0.300	0.300	0
0.400	0.319	0.081

- A) 1.30×10^{-1} B) 3.25×10^{-2} C) 2.41×10^{-5}
 D) 6.03×10^{-6} E) 6.03×10^{-9}

20) Molecular hydrogen is an essential feedstock for the industrial production of ammonia. Due to the impracticality of transporting molecular hydrogen, it is produced at the site of ammonia production through *steam methane reforming*, as follows:

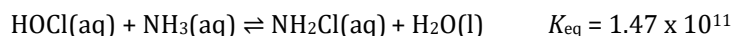


Given a starting steam (H_2O) to methane (CH_4) mole ratio of 2.5:1.0, an initial pressure of 28 atm, no starting carbon monoxide or molecular hydrogen, determine the K_p if 62.5% of the initial methane is converted to products. Assume *ideal gas* behaviour.

- A) 1.7×10^0 B) 1.4×10^1 C) 2.1×10^2
 D) 3.8×10^2 E) 5.6×10^3

CCC 2017

- 16) The smell often associated with public swimming pools comes from chloramines. The reaction of hypochlorous acid with ammonia from human urine will produce monochloramine (NH_2Cl) as follows:



One part per million (ppm) is a mg L^{-1} . A typical public swimming pool volume (750,000 L) contains 75.0 L of urine. The concentration of ammonia in 1 L of urine is 0.200 M. If the concentration of hypochlorous acid in pool water is 1.00 ppm, determine the concentration (in ppm) of monochloramine (NH_2Cl) in a typical public swimming pool. Assume the mass of 1 L of pool water is 1 kg.

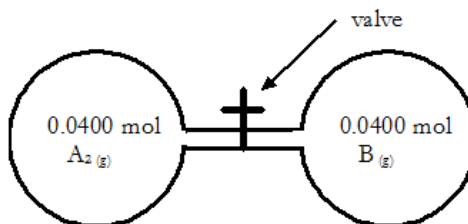
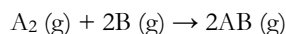
- A) 1.91 B) 1.64 C) 1.03 D) 1.00 E) 0.98

- 3) If the total pressure increases in each of the reaction mixtures below, for which reaction would the product yield remain unchanged at equilibrium?

- A) $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$
 B) $2 \text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{NOCl}(\text{g})$
 C) $2 \text{H}_2\text{S}(\text{g}) \rightleftharpoons 2 \text{H}_2(\text{g}) + \text{S}_2(\text{g})$
 D) $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{H}_2\text{O}(\text{g})$
 E) $3 \text{H}_2(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g})$

CCC 2016

- 12A) A student sets up two 1.00 L gas bulbs at 25.0 °C connected by a glass tube. The combined volume of one bulb and half of the tube is 1.00 L. The student opens the valve and allows 0.0400 moles of $\text{A}_2(\text{g})$ and 0.0400 moles of $\text{B}(\text{g})$ to mix. The reaction forms $\text{AB}(\text{g})$. What is the final pressure (kPa) in the 2.00 L system if the reaction proceeds to completion and the temperature remains constant?

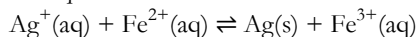


- A) 198 kPa B) 149 kPa C) 99.1 kPa D) 74.3 kPa E) 49.6 kPa

22. Milk of magnesia is sold at drugstores in Canada to treat indigestion or mild constipation. The active ingredient in milk of magnesia is magnesium hydroxide, $\text{Mg}(\text{OH})_2$. The solubility of $\text{Mg}(\text{OH})_2$ is $7.05 \times 10^{-3} \text{ g L}^{-1}$. What is the K_{sp} of magnesium hydroxide?

- A) 1.99×10^{-4} B) 1.40×10^{-6} C) 3.50×10^{-7}
 D) 1.46×10^{-8} E) 7.06×10^{-12}

24. Which of the following would cause the precipitation of more silver in the equilibrium which is exothermic in the forward direction.



- A) Increasing the temperature
 B) Increasing the volume of water
 C) Removing some of the solid silver precipitate
 D) Increasing the concentration of Fe^{3+} ions
 E) Increasing the concentration of Fe^{2+} ions

25. Given the following equilibria,

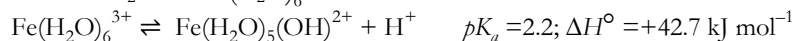
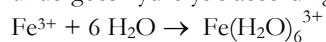


Which salt is the most **alkaline** from among the options below?

- A) NaCN B) NaCH_3COO C) NH_4Cl D) $\text{NH}_4\text{CH}_3\text{COO}$ E) NH_4CN

CCC 2015

16. Iron(III) is readily hydrated in aqueous solution and subsequently undergoes hydrolysis according to the following equations:



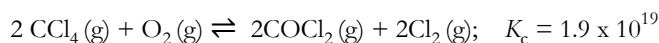
Predict the effect of an increase in temperature on the pK_a and the $[\text{H}^+]$ of the solution.

- A) pK_a increases, $[\text{H}^+]$ decreases B) pK_a increases, $[\text{H}^+]$ increases
 C) pK_a decreases, $[\text{H}^+]$ decreases D) pK_a decreases, $[\text{H}^+]$ increases
 E) pK_a unchanged, $[\text{H}^+]$ unchanged

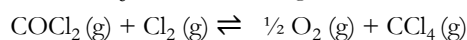
7. Calcium fluoride, CaF_2 , occurs in nature principally as the mineral *fluorite* and is the primary source of industrial hydrogen fluoride. Determine the concentration of fluoride ions in a saturated solution of calcium fluoride with $[\text{Ca}^{2+}] = 0.0250 \text{ mol L}^{-1}$. K_{sp} for calcium fluoride is 3.45×10^{-11} .
- A) $1.38 \times 10^{-9} \text{ mol L}^{-1}$ B) $2.76 \times 10^{-9} \text{ mol L}^{-1}$ C) $5.87 \times 10^{-6} \text{ mol L}^{-1}$
 D) $3.71 \times 10^{-5} \text{ mol L}^{-1}$ E) $.85 \times 10^{-5} \text{ mol L}^{-1}$
21. Hemoglobin is the iron-containing protein in red blood cells that transports oxygen to cells and tissues. Four oxygen molecules bond with each hemoglobin molecule to form oxygenated hemoglobin, $\text{Hb}(\text{O}_2)_4$. The production of oxygenated hemoglobin can be depicted by the following equilibrium: $\text{Hb}_{(aq)} + 4 \text{O}_{2(g)} \rightleftharpoons \text{Hb}(\text{O}_2)_4_{(aq)}$. At high altitudes, the total atmospheric pressure decreases and thus the partial pressure of oxygen decreases. With insufficient oxygenated hemoglobin, a person will feel light-headed and eventually lose consciousness. Which of the following statements is TRUE about the hemoglobin equilibrium reaction as a person climbs to a high altitude?
- A) The concentration of the products increases
 B) The rate of the reverse reaction increases
 C) The reaction quotient (Q) will increase
 D) The concentrations of the aqueous solutions will not change
 E) The value of the equilibrium constant increases

CCC 2014

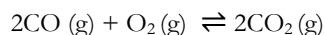
20. Carbon tetrachloride reacts with oxygen at high temperatures to produce chlorine and carbonyl chloride



Calculate the K_c for the following reaction:



- A) 5.3×10^{-20} B) -1.9×10^{19} C) -9.5×10^{-20}
 D) 9.5×10^{-20} E) 2.3×10^{-10}
16. What is the numerical value of the equilibrium constant for the reaction



if the equilibrium concentrations are $[\text{CO}] = 2.0 \text{ mol L}^{-1}$,
 $[\text{O}_2] = 1.0 \text{ mol L}^{-1}$, and $[\text{CO}_2] = 8.0 \text{ mol L}^{-1}$?

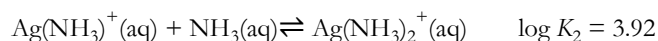
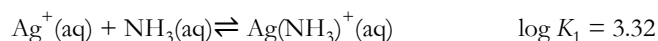
- A) 1.0 B) 4.0 C) 8.0 D) 16 E) 32
18. Given the solubility product constant (K_{sp}) of silver phosphate (Ag_3PO_4) is 1.8×10^{-18} , the concentration of silver ions (in mol L^{-1}) in a saturated solution of silver phosphate is:
- A) 2.6×10^{-10} B) 1.3×10^{-6} C) 1.6×10^{-5}
 D) 3.7×10^{-5} E) 4.8×10^{-5}

CCC 2013

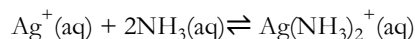
25. Car batteries consist of lead/lead(IV) oxide plates suspended in sulfuric acid. Lead(II) sulfate gradually forms during the discharge process. If an equilibrated mixture of lead(II) sulfate in water is filtered, and 50.0 mL of the filtrate is added to 50.0 mL of sodium sulfate solution (1.0 mol L^{-1}), some lead(II) sulfate precipitates out. What is the concentration of lead(II) ions remaining in solution? ($K_{sp}(\text{PbSO}_4) = 1.6 \times 10^{-8}$, values are at 25°C .)

- A. $8.0 \times 10^{-9} \text{ mol L}^{-1}$ B. $1.6 \times 10^{-8} \text{ mol L}^{-1}$ C. $3.2 \times 10^{-8} \text{ mol L}^{-1}$
 D. $1.3 \times 10^{-4} \text{ mol L}^{-1}$ E. $2.2 \times 10^{-3} \text{ mol L}^{-1}$

15. Silver ions are more soluble in aqueous ammonia solution than in water due to the formation of complexes. Information about the sequential equilibria involved at 298K is as follows:



What is the equilibrium constant, K_C , for the following process?



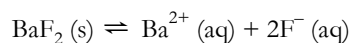
- A. 7.02 B. 7.24 C. 13.01 D. 1.04×10^7 E. 1.74×10^7

22. What is the result of an increase in the temperature of a system at equilibrium?

- A. The endothermic reaction is favoured and the rate of this reaction decreases.
 B. The exothermic reaction is favoured and the rate of this reaction decreases.
 C. The endothermic reaction is favoured and the rate of this reaction increases.
 D. The exothermic reaction is favoured and the rate of this reaction increases.
 E. The activation energy for the forward reaction becomes smaller.

CCC 2012

10. A saturated solution of BaF_2 is obtained when 6.3×10^{-3} moles of BaF_2 are dissolved in 1 litre of water. What is the K_{sp} of barium fluoride?



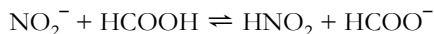
- A. 6.3×10^{-3} B. 2.5×10^{-5} C. 4.0×10^{-5} **D. 1.0×10^{-6}** E. 2.5×10^{-7}

22. An equilibrium is established when one mole of hydrogen gas reacts with one mole of solid iodine and 51.8 kJ of energy (heat) are supplied. The product of the reaction is gaseous hydrogen iodide. The correct equilibrium constant expression for this reaction is:

- A. $\frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]}$ B. $\frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$ C. $[\text{H}_2][\text{I}_2]$
 D. $\frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$ **E. $\frac{[\text{HI}]^2}{[\text{H}_2]}$**

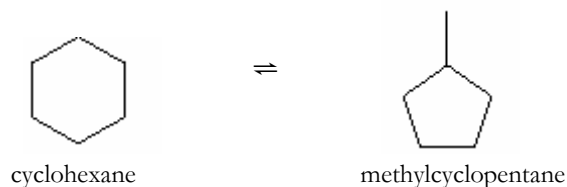
CCC 2011

12. Given K_a values of 1.8×10^{-4} and 6.8×10^{-4} for methanoic acid (HCOOH) and nitrous acid (HNO_2) respectively, calculate the equilibrium constant for the following reaction.



- A. 8.6×10^{-4} B. 0.26 C. 1.2×10^{-7} D. 5.0×10^4 E. 3.8

22. Cyclohexane undergoes a molecular rearrangement in an inert solvent and the presence of AlCl_3 to form methylcyclopentane, according to the equation:



If $K_c = 0.143$ at 25°C for this reaction, find the equilibrium concentrations of cyclohexane and methylcyclopentane if the initial concentrations are 0.200 mol L^{-1} and 0.075 mol L^{-1} , respectively.

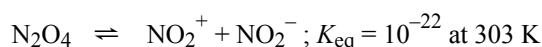
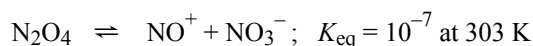
- A. [cyclohexane] = 0.041 mol L^{-1} , [methylcyclopentane] = 0.234 mol L^{-1}
 B. [cyclohexane] = 0.159 mol L^{-1} , [methylcyclopentane] = 0.116 mol L^{-1}
 C. [cyclohexane] = 0.241 mol L^{-1} , [methylcyclopentane] = 0.034 mol L^{-1}
 D. [cyclohexane] = 0.253 mol L^{-1} , [methylcyclopentane] = 0.022 mol L^{-1}
 E. [cyclohexane] = 0.257 mol L^{-1} , [methylcyclopentane] = 0.018 mol L^{-1}

CCC 2010

14. Zinc hydroxide is used in surgical dressings. Given that its solubility product constant, $K_{\text{SP}}(\text{Zn}(\text{OH})_2) = 4.15 \times 10^{-17}$, what is the concentration of hydroxide ions in a saturated solution of zinc hydroxide?

- A. $2 \times 10^{-6} \text{ mol L}^{-1}$ B. $1.5 \times 10^{-6} \text{ mol L}^{-1}$ C. $3.5 \times 10^{-6} \text{ mol L}^{-1}$
 D. $4 \times 10^{-6} \text{ mol L}^{-1}$ E. $6.9 \times 10^{-6} \text{ mol L}^{-1}$

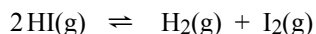
15. Dinitrogen tetroxide is often a component in smog: it is corrosive, highly toxic and oxidising. It undergoes three different types of self dissociation according to the following equations:



Assuming that no other reactions are taking place, which one of the following species will be present in the greatest concentration at 303K?

- A. O^+ B. O_2^+ C. O_2^- D. NO_3^- E. N_2O_4

20. A test for hydrogen iodide (a colourless gas) is to insert a hot platinum rod into the gas, which will then turn purple due to the formation of iodine gas according to the following equation:

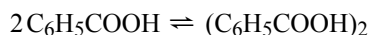


Based on this information, which combination of the following statements about the forward reaction is correct:

	Type of reaction	Enthalpy
A.	Endothermic	Decreases
B.	Endothermic	Increases
C.	Exothermic	Decreases
D.	Exothermic	Increases
E.	Neither exothermic nor endothermic	Does not change

CCC 2009

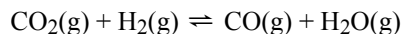
18. In benzene solution, benzoic acid forms an equilibrium mixture with its dimer (double molecule), as shown in the following equation:



If the concentration of benzoic acid in the initial solution is 0.1 mol L^{-1} , and the concentration of dimer in the equilibrium solution is $x \text{ mol L}^{-1}$, then which of the following expressions for the equilibrium constant is correct?

- A. $x/(0.1 - x)^2$ B. $x/(0.2 - x)^2$ C. $x/2(0.1 - x)^2$
 D. $x/(0.1 - x)$ E. $x/(0.1 - 2x)^2$

25. The In Situ Resource Utilization research for Mars has been evaluating a reaction between CO_2 (found in the Martian atmosphere) and H_2 (brought from Earth). This reaction produces water that can be electrolysed to give O_2 for use in the propellant needed for returning a rocket to Earth. The essential reaction is:

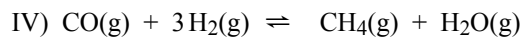
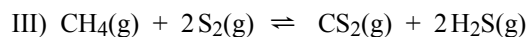
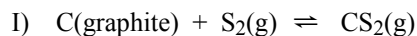


The reaction is performed at 400°C with Fe/Cr as catalyst. If equimolar amounts of CO_2 and H_2 are mixed in a closed container, what is the approximate molar percentage of water in the mixture at equilibrium? ($K_{\text{eq}} \approx 0.5$ at 400°C)

- A. 16% B. 20% C. 25% D. 33% E. 50%

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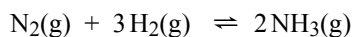
20. Consider the following reactions:



Assuming that each of these reactions has achieved equilibrium, which two would NOT then be affected by an increase in pressure (by reducing the volume, and with the temperature kept constant)?

A. I and II B. I and III C. I and IV D. II and III E. II and IV

23. The following equilibrium reaction is the basis for the production of ammonia used in fertilizers:



If the equilibrium constant for this reaction is K , then which one of the following will be the equilibrium constant when the concentration of hydrogen gas in the mixture is doubled (at the same temperature)?

A. $K/8$ B. $K/4$ C. K D. $2K$ E. K^2

9. Aluminum hydroxide ($M_r = 78.0$) is used in the dyeing industry. What mass (in kg) will be required to saturate 1000 L of water at 298 K if the solubility product constant $K_{sp}\{\text{Al}(\text{OH})_3\} = 1.0 \times 10^{-32}$ at 298 K?

A. $\{1.0 \times 10^{-32}/27\}^{1/4} \times 78.0$ B. $\{1.0 \times 10^{-32}/27\}^{1/4} \div 78.0$
 C. $\{1.0 \times 10^{-32}/27\}^{1/3} \times 78.0$ D. $\{1.0 \times 10^{-32}/81\}^{1/3} \div 78.0$
 E. $\{1.0 \times 10^{-32}/81\}^{1/4} \times 78.0$

CCC 2007