Worksheet: Equilibrium Constants and Concentrations

In this worksheet, we will practice converting between equilibrium constant expressions and the concentrations of reactants and products.

Q1: Consider the equilibrium of the HPO_4^{2-} ion acting as a weak base:

$$HPO_4^{2-}(aq) + H_2O(l) <=> H_2PO_4^{-}(aq) + OH^{-}(aq).$$

A solution containing a mixture of NaH_2PO_4 and Na_2HPO_4 at equilibrium has the following concentrations:

$[OH^-] = 1.3 \times 10^{-6}$ M,

$[H_2PO_4^-] = 0.042$ M,

$[HPO_4^{2-}] = 0.341$ M. What is the equilibrium constant for this reaction under these conditions?

A 1.1×10^{-5}

B 5.5×10^{-8}

C 1.6×10^{-7}

D 4.4×10^{-7}

Q2: Consider the equilibrium

$$N_2(g) + 3\,H_2(g) <=> 2\,NH_3(g), \quad K_c = 0.50 \text{ at } 400°C.$$

Analysis of the gases in a sealed reaction vessel containing NH_3, N_2, and H_2 at equilibrium at 400°C established the concentration of N_2 to be 1.2 M and the concentration of H_2 to be 0.24 M. What is the equilibrium molar concentration of NH_3?

A 0.14 M

B 8.3×10^{-3} M

C 0.38 M

D 9.1×10^{-2} M

E 10 M

Q3: Cobalt metal can be prepared by reducing cobalt(II) oxide with carbon monoxide, as shown in the equation:

$$CoO(s) + CO(g) <=> Co(s) + CO_2(g), \quad K_c = 4.90 \times 10^2 \text{ at } 550°C.$$

What concentration of CO remains in an equilibrium mixture with $[CO_2] = 0.100$ M?

A 490 M

B 2.04×10^{-4} M

C 4 900 M

D 0.100 M

E Not enough information is provided.

Q4: Carbon is reacted with water vapor at 1 000°C, establishing the equilibrium

$$C(s) + H_2O(g) <=> CO(g) + H_2(g), \quad K_c = 0.200 \text{ at } 1\,000°C.$$

What is the concentration of CO in the equilibrium mixture if $[H_2O] = 0.750$ M?

A 0.375 M

B 2.58 M

C 2.86 M

D 0.387 M

E 0.200 M

Q5: Consider the equilibrium

$$N_2O_4(chloroform) <=> 2\,NO_2(chloroform), \quad K_c = 1.07 \times 10^{-5}.$$

What is the equilibrium concentration of NO_2 in 1.00 L of a solution prepared from 0.129 mol of N_2O_4 with chloroform as the solvent? Assume that the change in concentration of N_2O_4 is small enough to be neglected.

A 1.38×10^{-8} M

B 6.90×10^{-7} M

C 1.17×10^{-3} M

D 5.87×10^{-4} M

E 8.29×10^{-5} M

Q6: Pure PCl_5 decomposes reversibly into PCl_3 and Cl_2:

$$PCl_5(g) <=> PCl_3(g) + Cl_2(g), \quad K_c = 0.0211.$$

The initial concentration of PCl_5 is 2.00 M. Calculate the equilibrium concentration of Cl_2.

A 0.216 M

B 0.145 M

C 0.205 M

D 0.195 M

E 0.135 M

Q7: What is the concentration of NO in an equilibrium mixture at 250°C that results from the reaction of 0.20 MNO and 0.10 MO_2?

$$2\,NO(g) + O_2(g) <=> 2\,NO_2(g), \quad K_c = 2.3 \times 10^5 \text{ at } 250°C.$$

A 0.0056 M

B 0.0035 M

C 0.012 M

D 0.0070 M

E 0.0044 M

Q8: Consider the equilibrium

$$H_2 + I_2 <=> 2\,HI, \quad K_c = 50.2 \text{ at } 448°C.$$

How many grams of HI are present in an equilibrium mixture containing 1.25 mol of H_2 and 63.5 g of I_2 at 448°C?

A 164 g

B 133 g

C 564 g

D 197 g

E 507 g

Q9: Consider the equilibrium

$$CaCO_3(s) <=> CaO(s) + CO_2(g).$$

What is the minimum mass of $CaCO_3$ required to establish equilibrium at a certain temperature in a 6.50-L container if the equilibrium constant (K_c) is 0.050 for the decomposition reaction of $CaCO_3$ at that temperature?

A 33 g

B 19 g

C 110 g

D 0.050 g

E 50 g

Q10: Carbon monoxide and water react at high temperature according to the equation:

$$CO(g) + H_2O(g) <=> CO_2(g) + H_2(g).$$

Under certain conditions, the equilibrium constant for this reaction (K_c) is 5.0.

An equilibrium mixture of the substances was found to contain 0.20 mol of CO, 0.30 mol of water vapor, and 0.90 mol of H_2 per liter of gas. How many moles of CO_2 were present in the equilibrium mixture?

A 0.33 mol

B 0.14 mol

C 0.67 mol

D 0.11 mol

E 0.90 mol

Additional H_2 was added to the system at the same temperature, and some water vapor was removed by drying. A new equilibrium mixture was thereby established containing 0.40 mol of CO, 0.30 mol of water vapor, and 1.2 mol of H_2 per liter of gas. How many moles of CO_2 were there in the new equilibrium mixture?

A 0.50 mol

B 1.0 mol

C 0.75 mol

D 1.5 mol

E 1.3 mol

Q11: Antimony pentachloride decomposes according to this equation:

$$SbCl_5(g) <=> SbCl_3(g) + Cl_2(g).$$

An equilibrium mixture in a 5.00 L flask at 448°C contains 3.85 g of $SbCl_5$, 9.14 g of $SbCl_3$, and 2.84 g of Cl_2. How many grams of antimony pentachloride would be present if this mixture were transferred into a 2.00 L flask at the same temperature?

A 15.8 g

B 4.72 g

C 3.85 g

D 6.21 g

E 12.0 g

Q12: Sucrose is hydrolyzed to fructose and glucose according to the equation:

$$C_{12}H_{22}O_{11}(aq) + H_2O(l) -> C_6H_{12}O_6(aq) + C_6H_{12}O_6(aq), \quad \text{rate} = k[C_{12}H_{22}O_{11}].$$

This reaction follows a first-order rate law. The products are structural isomers, exhibiting the same structural formula $C_6H_{12}O_6$.In neutral solution, $k = 2.1 \times 10^{-11}$ s^{-1} at 27°C. In the human body, the rate of this reaction is catalyzed by an enzyme, increasing the rate constant to 1.36×10^5 at 27°C. What is the concentration of fructose after a 0.150 M aqueous solution of sucrose has reached equilibrium?

A 9.71 M

B 0.266 M

C 3.00 M

D 1.50 M

E 7.35×10^{-6} M

Q13: Gaseous nitrogen dioxide forms dinitrogen tetroxide according to this equation:

$$2\,NO_2(g) <=> N_2O_4(g).$$

When 0.10 molNO_2 is added to a 1.0 L flask at 25°C, the concentration changes so that at equilibrium, $[NO_2] = 0.016$ M and $[N_2O_4] = 0.042$ M.

What is the value of the reaction quotient before any reaction occurs?

A Undefined

B 0

C 13

D 0.42

E 4.2

What is the value of the equilibrium constant for the reaction?

A 2.6

B 1.6×10^{2}

C 4.2

D 0.38

E 6.1×10^{-4}

Q14: For the reaction $2\,SO_2(g) + O_2(g) <=> 2\,SO_3(g)$, the concentrations at equilibrium are $[SO_2] = 0.90$ M, $[O_2] = 0.35$ M, and $[SO_3] = 1.1$ M. What is the value ofthe equilibrium constant, K_c?

A 0.27

B 3.5

C 0.23

D 4.3

E 9.6

Q15: Iodine molecules react reversibly with iodide ions to produce triiodide ions:

$$I_2(aq) + I^-(aq) <=> I_3^-(aq).$$

Before a reaction, the concentrations of I_2 and I^- in a solution are both equal to 1.000×10^{-3} M. At equilibrium, the concentration of I_2 is 6.61×10^{-4} M. If the concentrations of all species are 1.000 M under standard conditions, calculate the equilibrium constant for this reaction.

A 6.61×10^{-4}

B 1.29×10^{-3}

C 111

D 0.209

E 776

Q16: Ethanol and acetic acid react to form water and ethyl acetate, the solvent responsible for the odor of some nail polish removers:

$$C_2H_5OH + CH_3CO_2H <=> CH_3CO_2C_2H_5 + H_2O.$$

When 1.00 mol each of C_2H_5OH and CH_3CO_2H are allowed to react in 1.00 L of the solvent dioxane, equilibrium is established when $\frac{1}{3}$ mol of each of the reactants remains. What is the equilibrium constant, K_c, for the reaction?

A 0.811

B 0.256

C 4.00

D 6.77×10^{-3}

E 6.04

Q17: The equilibrium constant for the reaction of nitrogen and hydrogen to produce ammonia at a certain temperature is 6.00×10^{-2}. What is the equilibrium concentration of ammonia if the equilibrium concentrations of nitrogen and hydrogen are 4.26 M and 2.09 M, respectively?

A 7.81 M

B 2.10 M

C 1.53 M

D 5.50 M

E 0.213 M

Q18: Under certain conditions, the equilibrium constant K_c for the decomposition of $PCl_5(g)$ into $PCl_3(g)$ and $Cl_2(g)$ is 0.0211. What is the equilibrium concentration of PCl_5 if the initial concentration of PCl_5 is 1.00 M?

A 0.730 M

B 0.422 M

C 0.291 M

D 0.865 M

E 0.145 M

Q19: Acetic acid, CH_3CO_2H, reacts with ethanol, C_2H_5OH, to form water and ethyl acetate, $CH_3CO_2C_2H_5$:

$$CH_3CO_2H + C_2H_5OH <=> CH_3CO_2C_2H_5 + H_2O.$$

The equilibrium constant for this reaction in dioxane is 4.0. A dioxane solution contains 0.15 M acetic acid, 0.15 M ethanol, 0.40 M ethyl acetate and 0.40 M water when initially prepared. Calculate the concentration of ethyl acetate at equilibrium.

A 0.15 M

B 0.37 M

C 0.45 M

D 0.60 M

E 0.22 M

Q20: Consider the equilibrium

$$H_2(g) + I_2(g) <=> 2\,HI(g).$$

A 1.00 L flask is filled with 1.00 mole of H_2 and 2.00 moles of I_2. The value of the equilibrium constant for the reaction of hydrogen and iodine reacting to form hydrogen iodide is 50.5 under the given conditions. Calculate the equilibrium concentration of HI in the 1.00 L flask.

A 1.87 M

B 0.470 M

C 0.948 M

D 3.00 M

E 2.00 M

Q21: Consider the equilibrium

$$HCN(aq) <=> H^+(aq) + CN^-(aq), \quad K_c = 4.9 \times 10^{-10}.$$

What is the approximate concentration of H^+ at equilibrium for a 0.15 M solution of HCN?

A 4.9×10^{-7} M

B 1.5×10^{-5} M

C 2.1×10^{-2} M

D 8.6×10^{-6} M

E 0.15 M

Q22: Consider the equilibrium

$$NH_3(aq) + H_2O(l) <=> NH_4^+(aq) + OH^-(aq), \quad K_c = 1.8 \times 10^{-5}.$$

What is the equilibrium concentration of NH_4^+ in a 0.25 M aqueous solution of NH_3?

A 3.6×10^{-4} M

B 1.8×10^{-3} M

C 2.1×10^{-3} M

D 4.5×10^{-2} M

E 9.1×10^{-3} M

Q23: Copper(II) ions form a complex ion in the presence of ammonia:

$$Cu^{2+}(aq) + 4NH_3(aq) <=> Cu(NH_3)_4^{2+}(aq), \quad K_c = 5.0 \times 10^{13}.$$

If 0.010 molCu^{2+} is added to 1.00 L of a 1.00 MNH_3 solution, what is the concentration of Cu^{2+} when the system comes to equilibrium?

A 2.1×10^{-16} M

B 6.7×10^{-15} M

C 7.0×10^{-16} M

D 1.1×10^{-15} M

E 2.4×10^{-16} M

Q24: Consider the equilibrium

$$\mathrm{Ni^{2+}}(aq) + 6\,\mathrm{NH_3}(aq) <=> \mathrm{Ni(NH_3)_6^{2+}}(aq), \quad K_c = 5.5 \times 10^8.$$

What is the approximate equilibrium concentration of $\mathrm{Ni^{2+}}$ when 0.25 mol $\mathrm{Ni^{2+}}$ is added to 1.00 L of a 2.00 M $\mathrm{NH_3}$ solution?

A 1.7×10^{-10} M

B 5.5×10^{-11} M

C 2.9×10^{-8} M

D 1.7×10^{-9} M

E 1.9×10^{-9} M

Q25: The equilibrium constant, K, of a process may change if it is calculated relative to different standard conditions. For which process does the choice of standard conditions have no effect on K?

A $\mathrm{H^+}(aq) + \mathrm{Cl^-}(aq) -> \mathrm{HCl}(aq)$

B $\mathrm{Cl_2}(g) -> 2\,\mathrm{Cl}(g)$

C $\mathrm{Br_2}(g) + \mathrm{Cl_2}(g) -> 2\,\mathrm{BrCl}(g)$

D $\mathrm{CaCO_3}(s) -> \mathrm{CaO}(s) + \mathrm{CO_2}(g)$

E $\mathrm{H_2CO_3}(aq) -> \mathrm{H_2O}(l) + \mathrm{CO_2}(aq)$