Name _____

SL Score /36

Key

**Practice Exam: Paper 2**
**Topic 7: Equilibrium**
**Topic 8: Acids & Bases**

**1.** Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) - (d).

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(a) Write the equilibrium constant expression for the reaction.

$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$ (1)

(b) (i) State the catalyst most often used in the Contact process.

$V_2O_5$ (1)

(ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction.

A catalyst will increase both the forward and reverse rates of reaction by lowering $E_a$, but it will not effect the value of $K_c$. (2)

(c) Use the collision theory to explain why increasing the temperature increases the rate of the reaction between sulfur dioxide and oxygen.

more effective collisions with sufficient activation energy ($E_a$). (2)

(d) Using Le Chatelier's principle state and explain the effect on the position of equilibrium of

(i) increasing the pressure at constant temperature.

Reaction will shift to the right to decrease the overall pressure (fewer moles of gas) (2)

(ii) removing of sulfur trioxide.

Shifts to the right to produce more $SO_3$. (2)

(iii) using a catalyst.

No effect, a catalyst will only increase the reaction rate. (2)

**2.** ~~In the gaseous state, methane~~ and steam react to form hydrogen and carbon dioxide.

(i) Write an equation for this endothermic equilibrium reaction. Deduce the equilibrium expression for the reaction and state its units.

$CH_4(g) + 2H_2O(g) \rightarrow 4H_2(g) + CO_2(g)$ (2)

$K_c = \frac{[H_2]^4[CO_2]}{[CH_4][H_2O]^2}$ ; units $= \frac{[\ ]^{2nd}[\ ]}{[\ ][\ ]^2} = [\ ] = \boxed{mol^2\,dm^{-6}}$ $\left(= \frac{mol^2}{L^2}\right)$

(ii) State the conditions of temperature and pressure under which the forward reaction is favoured.

High temperature (rxn is endothermic)
Low pressure (products have fewer moles of gas) (1)

1

3. Define the terms *strong acid* and *weak acid*. Using hydrochloric and ethanoic acid as examples, write equations to show the dissociation of each acid in aqueous solution.

Strong acids completely ionize

$HCl \rightarrow H^+ + Cl^-$

Weak acids only partially ionize

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

(3)

4. observations only!

(i) Calcium carbonate is added to separate solutions of hydrochloric acid and ethanoic acid of the same concentration. State **one** similarity and **one** difference in the observations you could make.

Similarity: Both acids will react with $CaCO_3$, producing a gas (or bubbles).

Difference: HCl would produce a more vigorous reaction, as it's a strong acid.

(2)

(ii) Write an equation for the reaction between hydrochloric acid and calcium carbonate.

$2HCl(aq) + CaCO_3(s) \rightarrow CO_2(g) + CaCl_2(aq) + H_2O(l)$

(phases not needed!)

(2)

(iii) Determine the volume of 1.50 mol ~~dm$^{-3}$~~ $L^{-1}$ hydrochloric acid that would react with exactly 1.25 g of calcium carbonate. ← to make work more familiar

$1.25\,g\,CaCO_3 \times \frac{1\,mol}{100.09\,g} \times \frac{2\,mol\,HCl}{1\,mol\,CaCO_3} \times \frac{1\,L}{1.50\,mol\,HCl} =$

(recall, $1\,dm^3 = 1\,L$)

$0.0167\,L$

$= \boxed{0.0167\,dm^3}$

STP!

(iv) Calculate the volume of carbon dioxide, measured at 273 K and $1.01\times10^5$ Pa, which would be produced when 1.25 g of calcium carbonate reacts completely with the hydrochloric acid.

$1.25\,g\,CaCO_3 \times \frac{1\,mol}{100.09\,g} \times \frac{1\,mol\,CO_2}{1\,mol\,CaCO_3} \times \frac{22.4\,L}{mol} = 0.280\,L$

$= \boxed{0.280\,dm^3}$

(Note: $101.3\,kPa = 1.01\times10^5\,Pa$)

↑ ignore

(2)

**5.** The pH values of solutions of three organic acids of the same concentration were measured.

| | |
|---|---|
| acid X | pH = 5 |
| acid Y | pH = 2 |
| acid Z | pH = 3 |

(i) Identify which solution is the least acidic.

acid X

**(1)**

(ii) Deduce how the $[H^+]$ values compare in solutions of acids Y and Z.

The $[H^+]$ for acid Y is 10 times more concentrated than acid Z.

**(2)**

(iii) Arrange the solutions of the three acids in decreasing order of electrical conductivity, starting with the greatest conductivity, giving a reason for your choice.

Y > Z > X

The stronger the acid, the greater the concentration of $H^+$.

(i.e., ions increase electrical conductivity)

**(2)**

**6.** The equilibrium reached when ethanoic acid is added to water can be represented by the following equation:

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Define the terms Brønsted-Lowry acid and Lewis base, and identify two examples of each of these species

A Bronsted-Lowry acid is a proton donor.

Examples: $CH_3COOH$ and $H_3O^+$

A Lewis base is an electron pair donor.

Examples: $H_2O$ and $CH_3COO^-$

**(3)**

**7.** Identify **one** example of a strong acid and **one** example of a weak acid. Outline **three** different methods to distinguish between equimolar solutions (i.e., same concentration) of these acids in the laboratory. State how the results would differ for each acid.

Strong Acid: HCl (or HBr, $HNO_3$, $HClO_4$, HI, $H_2SO_4$)

Weak Acid: $H_2CO_3$ (or $CH_3COOH$, HCN... nearly any other acid!)

Methods to distinguish:

1.) HCl would have a lower pH

2.) Electrical conductivity would be greater for HCl

3.) HCl would react more vigorously with Mg (or $CaCO_3$, ...) than would $H_2CO_3$, producing more gas bubbles and heat in a shorter period of time.

**(3)**