Equilibria – 2022 June AS Chemistry 9701

1. June/2022/Paper_11/No.13

Ethanoic acid is mixed with ethanol.

The ethanol is contaminated with a small amount of methanol.

The following equilibria are established.

$$CH_3CO_2H(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CO_2CH_2CH_3(l) + H_2O(l) \qquad K_c = K_1$$

$$CH_3CO_2H(l) + CH_3OH(l) \rightleftharpoons CH_3CO_2CH_3(l) + H_2O(l) \qquad K_c = K_2$$

Which statement about the equilibrium mixture is correct?

A Only ethyl ethanoate will be formed because there is much more ethanol present than methanol.

B In this mixture $\frac{[CH_3CO_2CH_2CH_3]}{[CH_3CO_2CH_3]} = \frac{K_1}{K_2}$.

C Adding water to the mixture will alter the mole ratio of the two esters.

D Adding methyl ethanoate to the mixture will increase the number of moles of ethyl ethanoate.

2. June/2022/Paper_11/No.14

SO_3 is manufactured from SO_2 and O_2 in the Contact process.

The reaction is exothermic.

Which row shows the effect on the equilibrium yield obtained in the Contact process of increasing the temperature and of adding a vanadium(V) oxide catalyst?

	increasing the temperature	adding vanadium(V) oxide as catalyst
A	equilibrium yield decreases	equilibrium yield increases
B	equilibrium yield decreases	equilibrium yield unchanged
C	equilibrium yield increases	equilibrium yield unchanged
D	equilibrium yield increases	equilibrium yield increases

3. June/2022/Paper_12/No.13

A synthesis for methanol is shown.

$$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O \qquad \Delta H = -49\,kJ\,mol^{-1}$$

Which conditions would produce the greatest yield of methanol at equilibrium?

	pressure	temperature / °C
A	high	80
B	high	20
C	low	80
D	low	20

4. June/2022/Paper_12/No.14

Hydrogen and iodine can react reversibly to produce hydrogen iodide. The equation is shown.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

4.00 mol of hydrogen gas and X mol of iodine vapour are mixed in a sealed container of volume 1.00 dm^3 at a temperature of 460 K. The system is allowed to reach equilibrium.

The equilibrium mixture contains 2.00 mol of hydrogen iodide. The equilibrium constant, K_c, for the reaction at 460 K is 4.0.

What is the value of X?

A 0.50 mol **B** 1.17 mol **C** 1.33 mol **D** 2.50 mol

5. June/2022/Paper_12/No.16

The Haber process for the manufacture of ammonia is represented by the equation shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which statement is correct about this reaction when the temperature is increased?

A Both forward and backward rates increase.

B The backward rate only increases.

C The forward rate only increases.

D There is no effect on the backward or forward rates.

6. June/2022/Paper_13/No.13

Which statement about acids and bases is **always** correct?

A An acid with two H atoms per molecule will be stronger than an acid with one H atom per molecule.

B A concentrated solution of a strong acid will have a lower pH than a dilute solution of a weak acid.

C A concentrated solution of a strong base will have a lower pH than a dilute solution of a weak base.

D A strong acid is more dissociated in solution than a strong base.

7. June/2022/Paper_13/No.14

The reaction between sulfur dioxide and oxygen is reversible.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur trioxide concentration is 6.00 mol dm^{-3}.

The sulfur dioxide concentration is twice the oxygen concentration.

What is the sulfur dioxide concentration?

A 0.175 mol dm^{-3}

B 0.252 mol dm^{-3}

C 0.318 mol dm^{-3}

D 0.636 mol dm^{-3}

8. June/2022/Paper_21/No.2(d)

(d) 25 cm^3 of 0.10 mol dm^{-3} HCl(aq) is added to a beaker and its pH is recorded.

50 cm^3 of 0.10 mol dm^{-3} NH_3(aq) is added to the HCl(aq) in 5 cm^3 portions.

The pH of the mixture is monitored until all the NH_3(aq) is added.

HCl is a strong Brønsted-Lowry acid.

(i) Describe what is meant by a strong Brønsted-Lowry acid.

.....

..... [2]

(ii) NH_3 is a weak base.

Construct an equation that shows the behaviour of NH_3 as a weak Brønsted-Lowry base when dissolved in water.

..... [1]

(iii) On Fig. 2.1 sketch a graph to show the change in pH which occurs when HCl(aq) is titrated with NH_3(aq) as described in **(d)**.

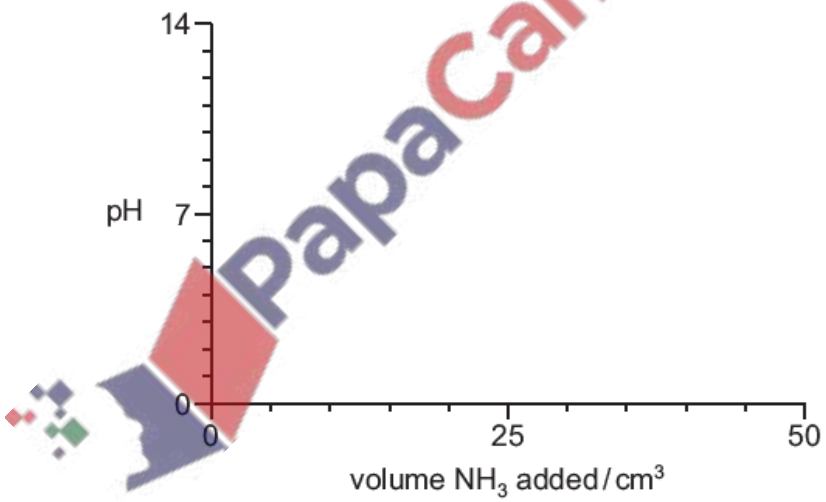

Fig. 2.1

[2]

9. June/2022/Paper_22/No.3(a_ d)

(a) 0.025 mol of HI(g) is added to a closed vessel and left to reach dynamic equilibrium. The total pressure of the vessel is 100 kPa.

equation **1** $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

(i) Explain what is meant by dynamic equilibrium.

.....

.....

..... [2]

(ii) Describe **one** difference in the initial appearance of the reaction mixture compared to the mixture at equilibrium.

..... [1]

(iii) Write an expression for K_p for the reaction described in equation **1**.

K_p =

[1]

(iv) At equilibrium the partial pressure of HI(g) is 86.4 kPa.

Calculate the amount of HI(g) present in the mixture at equilibrium. Show your working.

amount of HI(g) = ... mol [2]

(b) Use equation **1** and the bond energy values in Table 3.1 to calculate the change in enthalpy, ΔH, for the thermal decomposition of 1 mole of HI(g). Show your working.

Table 3.1

bond	bond energy / kJ mol^{-1}
H–H	436
I–I	151
H–I	299

ΔH = ... kJ mol^{-1} [2]

(c) Describe the effect of increasing pressure on the value of K_p for the decomposition of HI(g).

..... [1]

(d) HC*l*(g) is prepared by adding NaC*l*(s) to concentrated H_2SO_4.

HI(g) is **not** prepared by adding NaI(s) to concentrated H_2SO_4 because the HI(g) produced also reacts with concentrated H_2SO_4.

(i) Identify the type of reaction that occurs when NaI(s) reacts with concentrated H_2SO_4 to form HI(g).

..... [1]

(ii) Write an equation for the reaction of HI(g) and concentrated H_2SO_4.

..... [1]

(iii) Explain why HI(g) reacts with concentrated H_2SO_4 whereas HC*l* does not.

..... [1]

10. June/2022/Paper_22/No.3a(iii_ iv)

(iii) When **G**, $C_4H_{10}O$, is heated in a sealed container, an equilibrium mixture is produced.

$$C_4H_{10}O(g) \rightleftharpoons C_2H_6(g) + CO(g) + CH_4(g)$$

Complete the expression for the equilibrium constant, K_c, for this reaction.
State the units of K_c.

K_c =

units = ...
[2]

(iv) Thermal decomposition of **G** in the presence of I_2 affects the activation energy, E_a, for the reaction. Table 3.2 shows E_a for the thermal decomposition of **G** with and without I_2.

Table 3.2

reaction	E_a (with I_2) / kJ mol^{-1}	E_a / kJ mol^{-1}
$C_4H_{10}O(g) \rightarrow C_2H_6(g) + CO(g) + CH_4(g)$	143	224

State what effect adding I_2 to the reaction mixture has on the value of K_c.
Explain your answer.

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.....

..... [2]