Equilibria

Question Paper 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 1

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 Sulfuric acid is an important chemical with a variety of uses.

It is manufactured by the Contact process, the first stage of which involves the conversion of sulfur or a sulfide ore, such as galena, PbS, into sulfur dioxide, SO_2.

(a) **(i)** Write an equation for the reaction between galena and oxygen to form sulfur dioxide and lead(II) oxide.

..... [2]

(ii) Identify the oxidation number changes that take place during this reaction.

.....

..... [2]

(b) The second stage of the Contact process involves the production of sulfur trioxide, SO_3, from sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$$

(i) State the temperature usually chosen for this conversion and explain this in terms of reaction rates and Le Chatelier's principle.

temperature .....

explanation .....

.....

.....

..... [3]

(ii) State and explain the pressure conditions that would give the best rate and best yield of sulfur trioxide. Explain why these conditions are **not** actually used.

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..... [3]

(c) In the third stage of the process the sulfur trioxide is dissolved in 98% sulfuric acid followed by carefully controlled addition of water.

(i) Explain why the sulfur trioxide is not dissolved directly in water to produce sulfuric acid.

.....

..... [1]

(ii) Write equations for the reaction of sulfur trioxide with sulfuric acid and for the subsequent reaction with water.

.....

..... [2]

(d) Explain why sulfur dioxide is used as an additive in some foods and wines.

.....

.....

..... [2]

(e) The sulfur dioxide content of wine is most commonly measured by the Ripper Method which involves titration with iodine in the presence of starch as an indicator.

$$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow 2I^-(aq) + SO_4^{2-}(aq) + 4H^+(aq)$$

A 50.0 cm^3 sample of wine required 12.35 cm^3 of 0.010 mol dm^{-3} $I_2(aq)$ for complete reaction with the SO_2.

(i) How many moles of SO_2 are present in 50.0 cm^3 of wine?

moles of SO_2 in 50.0 cm^3 = ... [1]

(ii) How many moles of SO_2 are present in 1 dm^3 of wine?

moles of SO_2 in 1 dm^3 = ... [1]

(iii) How many milligrams, mg, of SO_2 are present in 1 dm^3 of wine? Give your answer to **three** significant figures. (1 g = 1000 mg)

mass of SO_2 in 1 dm^3 = ... mg [1]

[Total: 18]

2 (a) (i) What is meant by the term *buffer solution*?

.....

.....

..... [2]

(ii) Write equations to show how the hydrogencarbonate ion, HCO_3^-, controls the pH of blood.

.....

..... [2]

(iii) A solution containing both Na_2HPO_4 and NaH_2PO_4 is commonly used as a buffer solution. The following equilibrium is present in the solution.

$$H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H^+(aq) \qquad K_a = 6.2 \times 10^{-8}\,mol\,dm^{-3}$$

Calculate the pH of a buffer solution made by mixing 100 cm^3 of 0.5 mol dm^{-3} Na_2HPO_4 and 100 cm^3 of 0.3 mol dm^{-3} NaH_2PO_4.

(b) Silver phosphate, Ag_3PO_4, is sparingly soluble in water.

(i) Write an expression for the solubility product, K_{sp}, of Ag_3PO_4, and state its units.

pH = ... [2]

K_{sp} = units: ..... [1]

(ii) The numerical value of K_{sp} is 1.25×10^{-20} at 298 K. Use this value to calculate $[Ag^+(aq)]$ in a saturated solution of Ag_3PO_4.

$[Ag^+(aq)]$ = ... mol dm^{-3} [3]

(c) The half-equation for the redox reaction between phosphoric(III) acid and phosphoric(V) acid is shown.

$$H_3PO_4(aq) + 2H^+(aq) + 2e^- \rightleftharpoons H_3PO_3(aq) + H_2O(l) \qquad E^\ominus = -0.28\,V$$

Find suitable data from the *Data Booklet* to write an equation for the reaction between H_3PO_3 and $Fe^{3+}(aq)$ ions, and calculate the $E^\ominus_{cell}$ for the reaction.

equation: .....

$E^\ominus_{cell}$ = ... V [2]

[Total: 12]

3 Nitrogen dioxide, NO_2, can enter the atmosphere in a variety of ways.

(a) (i) State one natural and one man-made source of atmospheric NO_2.

natural .....

man-made .....

[1]

(ii) Write an equation to show how NO_2 leads to the formation of nitric acid in acid rain.

..... [1]

(iii) Use equations to illustrate the catalytic role of NO_2 in the formation of sulfuric acid in acid rain.

.....

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..... [3]

(b) Nitrogen dioxide exists in equilibrium with dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

2.00 mol of dinitrogen tetroxide was sealed in a container at 350 K. After equilibrium had been established the total pressure was 140 kPa and the mixture of gases contained 1.84 mol of dinitrogen tetroxide.

(i) Give the expression for the equilibrium constant, K_p, for this equilibrium.

K_p =

[1]

(ii) Calculate the number of moles of NO_2 present at equilibrium.

[1]

(iii) Calculate the total number of moles of gas present at equilibrium and hence the mole fraction of each gas present at equilibrium.

[2]

(iv) Calculate the partial pressure of each gas present at equilibrium.

[2]

(v) Calculate the value of the equilibrium constant, K_p, at 350 K.
Give your answer to **three** significant figures and include the units.

K_p = ...

units = ...
[2]

[Total: 13]

4 The Contact process for the manufacture of sulfuric acid was originally patented in the 19th century and is still in use today.

The key step in the overall process is the reversible conversion of sulfur dioxide to sulfur trioxide in the presence of a vanadium(V) oxide catalyst.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) One way in which the sulfur dioxide for this reaction is produced is by heating the sulfide ore iron pyrites, FeS_2, in air. Iron(III) oxide is also produced. Write an equation for this reaction.

..... [2]

(b) The sulfur trioxide produced in the Contact process is reacted with 98% sulfuric acid. The resulting compound is **then** reacted with water to produce sulfuric acid.

(i) Explain why the sulfur trioxide is not first mixed directly with water.

.....

..... [1]

(ii) Write equations for the two steps involved in the conversion of sulfur trioxide into sulfuric acid.

.....

..... [2]

(c) Sulfur dioxide and sulfur trioxide both contain only S=O double bonds.

Draw labelled diagrams to show the shapes of these two molecules.

SO_2 SO_3

[2]

(ii) For your diagrams in **(i)**, name the shapes and suggest the bond angles.

SO_2 shape ..... SO_3 shape .....

SO_2 bond angle ..... SO_3 bond angle .....

[2]

(d) The conversion of sulfur dioxide into sulfur trioxide is carried out at a temperature of 400 °C.

(i) With reference to Le Chatelier's Principle and reaction kinetics, state and explain one advantage and one disadvantage of using a higher temperature.

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.....

..... [4]

(ii) State the expression for the equilibrium constant, K_p, for the formation of sulfur trioxide from sulfur dioxide.

K_p =

[1]

(iii) 2.00 moles of sulfur dioxide and 2.00 moles of oxygen were put in a flask and left to reach equilibrium.
At equilibrium, the pressure in the flask was 2.00×10^5 Pa and the mixture contained 1.80 moles of sulfur trioxide.

Calculate K_p. Include the units.

K_p = ...

units = ...
[5]

[Total: 19]