12 One molecule of haemoglobin, Hb, can bind with four molecules of oxygen according to the equation shown.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

When the equilibrium concentration of O_2 is $7.6 \times 10^{-6}\,mol\,dm^{-3}$, the equilibrium concentrations of Hb and $Hb(O_2)_4$ are equal.

What is the numerical value of K_c for this equilibrium?

A 3.0×10^{20} **B** 1.3×10^{5} **C** 7.6×10^{-6} **D** 3.3×10^{-21}

12 An equilibrium can be represented by the equation shown.

$$P(aq) + Q(aq) \rightleftharpoons 2R(aq) + S(aq)$$

In a certain mixture, of volume $1.0\,dm^3$, the equilibrium concentration of Q is $10\,mol\,dm^{-3}$.

What will be the new equilibrium concentration of Q if 5.0 mol of pure Q is completely dissolved in the mixture?

A $15\,mol\,dm^{-3}$

B between $10\,mol\,dm^{-3}$ and $15\,mol\,dm^{-3}$

C $10\,mol\,dm^{-3}$

D between $5.0\,mol\,dm^{-3}$ and $10\,mol\,dm^{-3}$

13 In the Contact process, sulfur dioxide and oxygen react to form sulfur trioxide.

In the Haber process, nitrogen and hydrogen react to form ammonia.

Which statement about these processes is correct?

A K_p for the Haber process has no unit.

B In the Contact process, the value of K_p falls when pressure is increased at constant T.

C The Haber process uses a homogeneous catalyst.

D When V_2O_5 is used in the Contact process, the position of equilibrium is unchanged.

12 Nitrogen dioxide decomposes on heating according to the equation shown.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 4 mol of nitrogen dioxide were put into a $1\,dm^3$ container and heated to a constant temperature, the equilibrium mixture contained 0.8 mol of oxygen.

What is the value of the equilibrium constant, K_c, at the temperature of the experiment?

A $\dfrac{0.8^2 \times 0.8}{4^2}$ **B** $\dfrac{1.6 \times 0.8}{2.4^2}$ **C** $\dfrac{1.6^2 \times 0.8}{4^2}$ **D** $\dfrac{1.6^2 \times 0.8}{2.4^2}$

13 One particle of X reacts with one particle of Y in a single-step reaction to produce two particles of Z.

This reaction is exothermic and reversible.

$$X + Y \rightleftharpoons 2Z$$

Three statements about the forward and reverse reactions are listed.

1 The activation energy of the forward reaction is equal to the activation energy of the reverse reaction.

2 At equilibrium, the frequency of collisions between one particle of X and one particle of Y is equal to the frequency of collisions between two particles of Z.

3 At equilibrium, the frequency of effective collisions between one particle of X and one particle of Y is equal to the frequency of effective collisions between two particles of Z.

Which statements are correct?

A 1 only **B** 2 and 3 **C** 2 only **D** 3 only

1 Aqueous silver ions, $Ag^+(aq)$, react slowly with aqueous iron(II) ions, $Fe^{2+}(aq)$. An equilibrium is established.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

The concentration of $Ag^+(aq)$ at equilibrium can be determined by titration with a standard solution of aqueous potassium thiocyanate, KSCN(aq).

During the titration, the remaining $Ag^+(aq)$ ions react with $SCN^-(aq)$ ions to form a precipitate of AgSCN(s).

$$Ag^+(aq) + SCN^-(aq) \rightarrow AgSCN(s)$$

When all $Ag^+(aq)$ ions have been removed from solution, excess $SCN^-(aq)$ ions react with $Fe^{3+}(aq)$ to form a complex ion, $FeSCN^{2+}(aq)$, which has a red colour.

$$Fe^{3+}(aq) + SCN^-(aq) \rightarrow FeSCN^{2+}(aq)$$

The appearance of the red colour indicates the end-point.

A student carries out an experiment to determine the equilibrium constant, K_c.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^+(aq)]_{eqm}}$$

The student makes 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq) to use in the titration.

(a) Calculate the mass of solid potassium thiocyanate, KSCN(s), needed to make 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq).

mass of KSCN(s) = ... g [1]

(b) Describe how the student should make 250.0 cm^3 of 0.0200 mol dm^{-3} KSCN(aq) starting from the mass of KSCN(s) calculated in **(a)** in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [3]

(c) The student uses the following method to determine K_c.

step 1 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate, $AgNO_3(aq)$, into a dry conical flask. Label this flask **A**.

step 2 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous iron(II) sulfate, $FeSO_4(aq)$, into flask **A**.

step 3 Seal flask **A**, using a bung.

step 4 Allow flask **A** to stand for twelve hours.

step 5 Transfer 10.0 cm^3 of the mixture from flask **A** into another conical flask, flask **B**, without disturbing the precipitate in flask **A**.

step 6 Titrate the sample in flask **B** with 0.0200 mol dm^{-3} aqueous potassium thiocyanate, KSCN(aq).

step 7 Repeat steps 5 and 6 until concordant values are obtained.

(i) Suggest why flask **A** is sealed with a bung in step 3.

....

.... [1]

(ii) Suggest why flask **A** is left to stand for twelve hours in step 4.

....

.... [1]

(iii) Identify the precipitate in flask **A** in step 5.

[1]

(d) The student's results are shown in Table 1.1

Table 1.1

	rough titration	titration 1	titration 2	titration 3
final burette reading / cm^3	22.50	21.75	31.65	32.20
initial burette reading / cm^3	0.00	0.00	9.75	10.20
titre / cm^3	22.50	21.75	21.90	22.00

(i) State if concordant titres have been achieved.

Explain your answer.

....

.... [1]

(ii) Calculate the percentage error in the titre volume in titration 2.

Show your working.

percentage error = ... [1]

(iii) The student repeats the experiment using KSCN(aq) at a **higher** concentration. The student obtains **smaller** titres.

Suggest **one** reason why a larger titre is better than a smaller titre.

.... [1]

(e) Another student calculates a mean titre of 21.85 cm^3. Use this value to complete the following calculation.

(i) Calculate $[Ag^{+}(aq)]$ in the equilibrium mixture in flask **A**.

$[Ag^{+}(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(ii) Calculate $[Fe^{3+}(aq)]$ in the equilibrium mixture in flask **A**.

$[Fe^{3+}(aq)]_{eqm}$ = ... $mol\,dm^{-3}$ [1]

(iii) The formula for the equilibrium constant, K_c, is shown.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm}\,[Ag^{+}(aq)]_{eqm}}$$

Determine the value of K_c.

Give the units of K_c.

K_c = ...

units ....

[2]

(f) Several other students perform the same experiment at different temperatures. The K_c values that they obtain are used to produce the graph in Fig. 1.1.

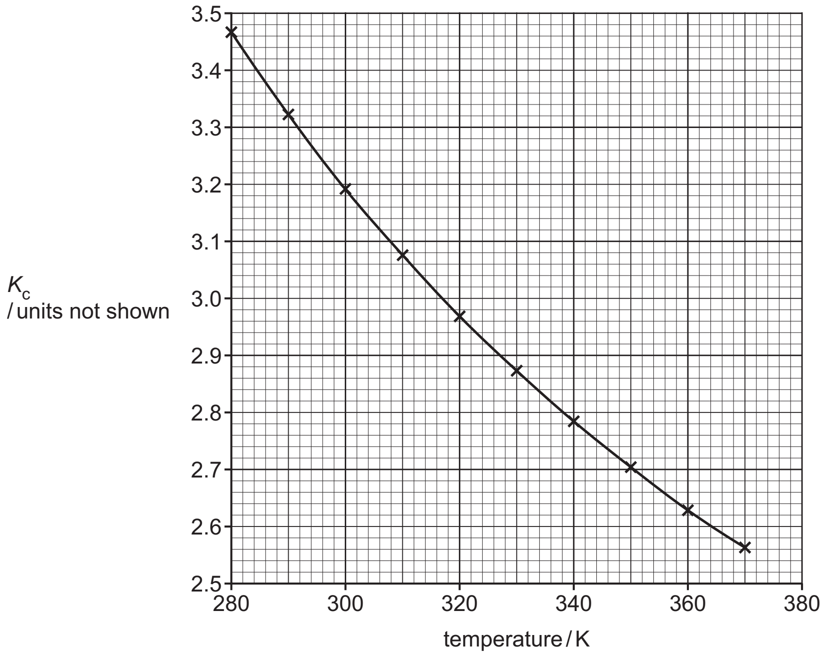

Fig. 1.1

(i) One student suggests that K_c is directly proportional to temperature.

State and explain if the results displayed in Fig. 1.1 support this suggestion.

....

.... [1]

(ii) Another student suggests that the data represented in the graph in Fig. 1.1 is reliable.

Explain how the graph supports this suggestion.

....

....

.... [1]

(iii) Use the data displayed in Fig. 1.1 to state if the forward reaction is exothermic or endothermic.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

Explain your answer.

forward reaction ....

explanation ....

....

....

[1]

[Total: 17]