Past-paper walk-through

Chemical equilibria: reversible reactions, dynamic equilibrium ▪ 7.1

eXercise

Questions in this set

- 9701/11 N25 Q12 ▪ 1 mark
- 9701/12 N25 Q12 ▪ 1 mark
- 9701/12 N25 Q13 ▪ 1 mark
- 9701/14 N25 Q12 ▪ 1 mark
- 9701/14 N25 Q13 ▪ 1 mark
- 9701/52 N25 Q1 ▪ 17 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 12

9701/11 N25 ▪ Q12 ▪ 1 mark

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}

Solution 12

Answer: **A**

Why

- $K_c = [\mathrm{Hb(O_2)_4}]/([\mathrm{Hb}][\mathrm{O_2}]^4)$.
- The two equal concentrations cancel, leaving $K_c = 1/[\mathrm{O_2}]^4$.
- $1/(7.6 \times 10^{-6})^4 = 1/(3.34 \times 10^{-21}) = 3.0 \times 10^{20}$.

Question 12

9701/12 N25 ▪ Q12 ▪ 1 mark

12 An equilibrium can be represented by the equation shown.

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

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 $mol\,dm^{-3}$

Solution 12

Answer: **B**

Why

- Adding 5.0 mol to 1.0 dm^3 momentarily raises $[\mathrm{Q}]$ to 15 mol dm^{-3}.
- Le Chatelier: the system shifts right to oppose the increase, using up some of the added Q.
- It cannot use all of it, so the new equilibrium value lies between 10 and 15.

Question 13

9701/12 N25 ▪ Q13 ▪ 1 mark

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.

Solution 13

Answer: **D**

Why

- A catalyst speeds up both directions equally, so it never moves the position of equilibrium – only the rate.
- K_p for the Haber process does have units, since the number of gas moles differs on the two sides.
- K_p depends only on temperature, so pressure cannot change it; and both processes use *solid* catalysts, making them heterogeneous.

Question 12

9701/14 N25 ▪ Q12 ▪ 1 mark

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** $\dfrac{1.6^2 \times 0.8}{2.4^2}$

Solution 12

Answer: **D**

Why

- 0.8 mol of O_2 means 1.6 mol of NO formed and 1.6 mol of NO_2 used up.
- So at equilibrium NO_2 is $4 - 1.6 = 2.4$ mol in 1 dm^3.
- $K_c = [\mathrm{NO}]^2[\mathrm{O_2}]/[\mathrm{NO_2}]^2 = (1.6)^2(0.8)/(2.4)^2$.

Question 13

9701/14 N25 ▪ Q13 ▪ 1 mark

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.

Question 13

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

Solution 13

Answer: **D**

Why

- Statement 1 fails: for an exothermic reaction the forward activation energy is the *smaller* of the two.
- Statement 2 fails: equilibrium fixes the *rates*, not the raw collision frequencies, which depend on concentrations.
- Statement 3 holds: at equilibrium the forward and reverse rates are equal, and rate is the frequency of *effective* collisions.

Question 1

9701/52 N25 ▪ Q1 ▪ 17 marks

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.

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

Question 1

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).

Question 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.

Question 1

(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, $KSCN(aq)$.

Question 1

Question 1

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.

Question 1

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

Question 1

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

Question 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.

Question 1

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

Show your working.

Question 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.

Question 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**.

Question 1

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

Question 1

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

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

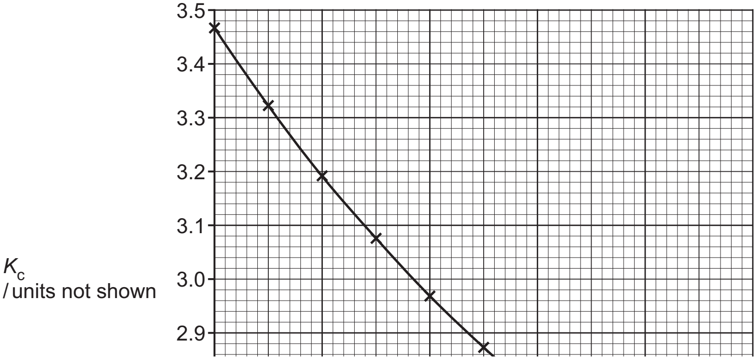
Determine the value of K_c.

Give the units of K_c.

Question 1

[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.



Question 1

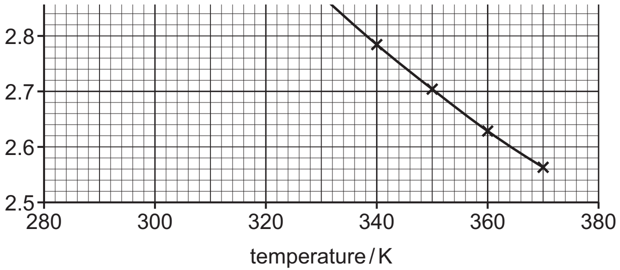


Fig. 1.1

(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.

Question 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.

Question 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.

Question 1

Question 1

[1]

[Total: 17]

Solution 1

(a)

Mark scheme

- 0.486 g
- 1

Solution 1

(b) Mark scheme

- M1 Dissolve the solid / KSCN(s) in (the beaker) (using a small volume of) (distilled) water M2
- Transfer/add to a (250 cm3 volumetric) flask
- and
- Rinse (with distilled water) M3
- Top the 250 cm3 volumetric flask up to mark (with distilled water)
- and
- Invert the (stoppered) flask

Solution 1

- Allow ‘250 volumetric flask’ (i.e. units need not be seen)
- 3

Solution 1

(c)(i)

Mark scheme

- to avoid oxidation (of contents of flask)
- 1

(c)(ii)

Mark scheme

- to ensure that equilibrium has been reached
- 1

Solution 1

(c)(iii)

Mark scheme

- Silver / Ag
- 1

Solution 1

(d)(i)

Mark scheme

- (yes)
- and
- two titres (2 and 3) are within 0.10 cm^3 (of each other)
- 1

Solution 1

(d)(ii)

Mark scheme

- Working must be shown
- $= 2\ 0.05$
- 21.90
- $\times$
- $\times\ 100 = 0.457\%$
- 1

Solution 1

(d)(iii)

Mark scheme

- percentage error (in larger titre) is lower
- 1

Solution 1

(e)(i)

Mark scheme

- 0.0437 mol dm–3
- 1

Solution 1

(e)(ii)

Mark scheme

- 0.00630 mol dm–3
- 1
- 9701/52
- October/November 2025

Solution 1

(e)(iii)

Mark scheme

- M1 Kc = 0.00630 / (0.04370)2 = 3.30
- 1 M2
- units = dm3 mol–1
- 1

Solution 1

(f)(i)

Mark scheme

- No
- and
- As temperature increases, Kc decreases
- 1

Solution 1

(f)(ii)

Mark scheme

- (data points that obey a line of best fit are reliable because) there are no anomalous points.
- 1

Solution 1

(f)(iii) Mark scheme

- exothermic
- and
- As temperature increases:
- Kc decreases
- or
- equilibrium shifts to left
- 1