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 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 7.6×10^{-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?

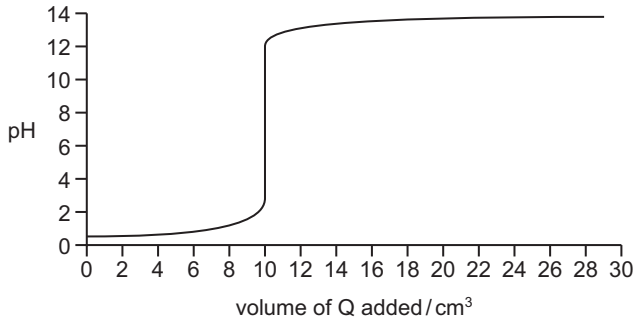
A 3.0×10^{20} **B** 1.3×10^{5} **C** 7.6×10^{-6} **D** 3.3×10^{-21}

13 Aqueous acid P and aqueous alkali Q have the same concentration.

20 cm^3 of P is added to a conical flask.

Q is slowly added to the flask and the volume of Q and the pH are recorded.

The pH titration curve is shown.



Which row gives the identity of P and Q?

	P	Q
A	HCl	NaOH
B	H_2SO_4	NH_3
C	HCl	$Ba(OH)_2$
D	CH_3COOH	$Sr(OH)_2$

14 Photochromic glass, used for sunglasses, darkens when exposed to bright light and becomes more transparent again when the light is less bright. The darkness of the glass is due to the presence of silver atoms.

The following reactions are involved.

reaction 1 $Ag^+ + Cl^- \rightleftharpoons Ag + Cl$

reaction 2 $Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$

reaction 3 $Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$

Which statement about these reactions is correct?

A Cu^+ and Cu^{2+} ions act as catalysts.

B Cu^+ ions act as an oxidising agent in reaction 2.

C Reaction 3 increases the darkness of the glass.

D Silver atoms are reduced in reaction 3.

1 Chromium, Cr, and its compounds are widely used in many chemical reactions.

(a) Cr exists as four stable isotopes.

(i) The most common isotope of Cr is chromium-52.

Determine the number of protons, neutrons and electrons in an atom of chromium-52.

number of protons ..... neutrons ..... electrons .....
[1]

(ii) Describe how an atom of chromium-54 differs from an atom of chromium-52. Refer to numbers of particles in your answer.

.....

..... [1]

(iii) The relative isotopic masses of the isotopes of Cr can be determined using mass spectrometry.

State what other information is needed to calculate the relative atomic mass, A_r, of Cr.

..... [1]

(iv) Atoms of ^{52}Cr, ^{53}Cr and ^{54}Cr make up more than 95% of naturally occurring chromium atoms. The A_r of naturally occurring Cr is 51.996.

Suggest what these statements imply about the relative isotopic mass of the fourth stable isotope of chromium.

..... [1]

(b) The shorthand electronic configuration of chromium is [Ar] $3d^5 4s^1$.

(i) Complete the full electronic configuration of chromium.

..... $3d^5 4s^1$ [1]

(ii) Deduce the total number of unpaired electrons in an atom of chromium.

..... [1]

(c) Acidified dichromate(VI) ions will convert methanal, CH_2O, to carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.

half-equation 1 $CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$

half-equation 2 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

(i) Identify the species that is reduced in half-equation 2. Explain your answer.

..... [1]

(ii) The oxidation state of the carbon atom in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

(iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

..... [2]

(iv) Methanal is a liquid at –30 °C but carbon dioxide is a gas at this temperature. Explain why.

.....

.....

.....

..... [2]

(d) In acidic conditions, a dynamic equilibrium is established between $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l) \qquad \Delta H > 0$$

(i) State what is meant by dynamic equilibrium.

.....

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii) $CrO_4^{2-}(aq)$ ions are yellow and $Cr_2O_7^{2-}(aq)$ ions are orange.

State what is observed when the following changes are made to an equilibrium mixture of acidified $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$ ions.

Explain your answers.

- The equilibrium mixture is warmed gently.

  observation .....

  explanation .....

  .....

  .....

- Dilute HC*l*(aq) is added to the equilibrium mixture.

  observation .....

  explanation .....

  .....

  .....

[4]

(e) Chromium(IV) fluoride, CrF_4, is a covalent molecule that shows similar chemical properties to SiCl_4.

Suggest the type of reaction that occurs when CrF_4 is placed in water.

Construct a relevant equation for this reaction.

type of reaction .....

equation .....

[2]

[Total: 20]

3 (a) (i) **FB 6**, **FB 7** and **FB 8** are aqueous solutions of different compounds that each contain at least one oxygen atom.

Carry out the following tests and record your observations in Table 3.1. Three of the tests have been done for you. Use a 1 cm depth of solution in a test-tube for each test.

Table 3.1

test	*observations*		
	FB 6	**FB 7**	**FB 8**
Test 1 Add a small spatula measure of manganese(IV) oxide.	No change.	No change.	
Test 2 Add a 1 cm length of magnesium.			No change.
Test 3 Add a few drops of aqueous iron(II) sulfate.			

[4]

(ii) Use your observations in Table 3.1 to suggest a possible formula for each of **FB 6**, **FB 7** and **FB 8**.

FB 6 .....

FB 7 .....

FB 8 .....

[2]

(b) **FB 9** contains two anions and two cations, three of which are listed in the Qualitative analysis notes.

(i) To a small spatula measure of **FB 9** in a test-tube, add a 2 cm depth of dilute nitric acid. Record your observations.

Keep the resulting solution for the test in (b)(ii).

.....

.....

..... [2]

(ii) To the solution from **(b)(i)**, add a few drops of aqueous silver nitrate. Then add excess aqueous ammonia. Record your observations.

.....

.....

..... [1]

(iii) Make an aqueous solution of **FB 9** by adding a 5 cm depth of distilled water to a spatula measure of **FB 9** in a test-tube. Carry out the following tests on the aqueous solution of **FB 9** and record your observations in Table 3.2.

Table 3.2

test	*observations*
Test 1 To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm.	
Test 2 To a 1 cm depth in a test-tube, add a few drops of dilute hydrochloric acid, then add a few drops of aqueous chlorine. **Empty and rinse the test-tube with water immediately after use.**	

[2]

(iv) Use your observations in **(b)(i)**, **(b)(ii)** and Table 3.2 to deduce the formulae of the cations and anions in **FB 9**. If you are unable to identify an ion, write 'unknown'.

cations ..... and .....

anions ..... and .....

[2]

(v) Write an ionic equation for the reaction in **(b)(ii)**. Include state symbols.

..... [1]

[Total:14]

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on warming	–
barium, Ba^{2+}(aq)	faint white ppt. is observed unless $[Ba^{2+}(aq)]$ is very low	no ppt.
calcium, Ca^{2+}(aq)	white ppt. unless $[Ca^{2+}(aq)]$ is very low	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives cream / off-white ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives pale yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; decolourises acidified aqueous $KMnO_4$
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids); gives white ppt. with high $[Ca^{2+}(aq)]$
sulfite, SO_3^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids); decolourises acidified aqueous $KMnO_4$
thiosulfate, $S_2O_3^{2-}$(aq)	gives off-white / pale yellow ppt. slowly with H^+

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	‘pops’ with a lighted splint
oxygen, O_2	relights a glowing splint