Past-paper walk-through

Stability constants, Kstab ▪ 28.5

eXercise

Questions in this set

- 9701/42 N25 Q6 ▪ 7 marks
- 9701/44 N25 Q1 ▪ 19 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 6

9701/42 N25 ▪ Q6 ▪ 7 marks

6 **(a)** Nickel forms complexes.

(i) Give the formula and charge of the tetrahedral complex formed by Ni atoms with carbon monoxide molecules. Carbon monoxide is a monodentate ligand. This is complex **E**.

Question 6

(ii) Give the formula and charge of the octahedral complex formed by Ni^{2+} ions with ethanedioate ions. This is complex **F**.

Question 6

(iii) Identify which complex, **E** or **F**, exists as a mixture of two stereoisomers and the type of stereoisomerism involved.

Question 6

Question 6

[1]

(b) Cadmium forms complexes with methylamine, CH_3NH_2, and 1,2-diaminoethane, *en*. The values of the stability constants, K_{stab}, of these complex ions are given in Table 6.1.

Table 6.1

complex	K_{stab}
$[Cd(CH_3NH_2)_4]^{2+}$	3.5×10^6
$[Cd(en)_2]^{2+}$	4.0×10^{10}

(i) Explain, by reference to its structure, why CH_3NH_2 acts as a monodentate ligand.

Question 6

(ii) Some $Cd^{2+}(aq)$ is added to a solution containing equal concentrations of CH_3NH_2 and *en*.

Predict which of the two complexes in Table 6.1 forms at the higher concentration.

Explain your answer.

Question 6

[1]

(iii) Complete the expression for the K_{stab} of $[Cd(CH_3NH_2)_4]^{2+}$.

K_{stab} =

[1]

[Total: 7]

Solution 6

(a)(i)

Mark scheme

- $Ni(CO)4$
- 1

Solution 6

(a)(ii) Mark scheme

- ▪
- ethanedioate given as C2O4
- ▪
- formula shows one Ni and three ligands
- ▪
- charge = 4–
- any two [1], all three [2]
- Ni(C2O4)34– scores [2]

Solution 6

- 2
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Solution 6

(a)(iii)

Mark scheme

- F AND optical
- 1

Solution 6

(b)(i)

Mark scheme

- N atom can donate one lone pair of electrons
- 1

(b)(ii)

Mark scheme

$Cd(en)_2^{2+}$ AND has a larger Kstab / is more stable

- 1

Solution 6

(b)(iii)

Mark scheme

(CH3NH2)4 2+]

Cd2+ [CH3NH2]4

- 1

Question 1

9701/44 N25 ▪ Q1 ▪ 19 marks

1 **(a)** Define a transition element.

Question 1

(b) The 3d orbitals in an isolated gaseous Cu^{2+} ion are degenerate.

(i) Define the term degenerate.

Question 1

(ii) Complete the electronic configuration of Cu^{2+}.

Question 1

(c) **(i)** State the colours of the aqueous solutions for the **two** copper(II) complex ions shown.

Question 1

Question 1

[1]

(ii) Explain why aqueous complex ions of transition elements are usually coloured.

Question 1

(d) **(i)** When an excess of $NH_3(aq)$ is added to a solution of $[CuCl_4]^{2-}(aq)$, $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is formed.

State the type of reaction.
Complete the equation for this reaction. State symbols are **not** required.

Question 1

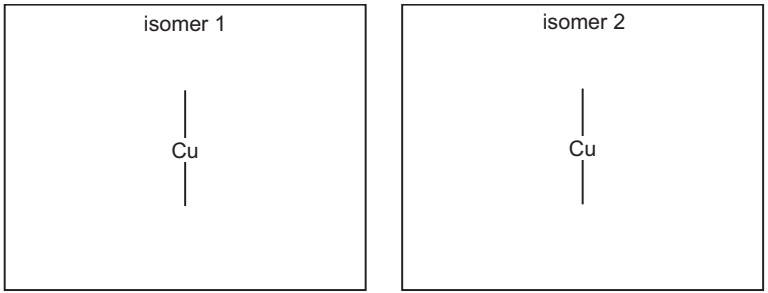
equation

Question 1

[2]

(ii) The $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion shows stereoisomerism.

Complete the three-dimensional diagrams in Fig. 1.1 to show the **two** different stereoisomers of $[Cu(NH_3)_4(H_2O)_2]^{2+}$.



Question 1

Fig. 1.1

Question 1

Fig. 1.1

[2]

(iii) Deduce which stereoisomer in **(d)(ii)** is polar.

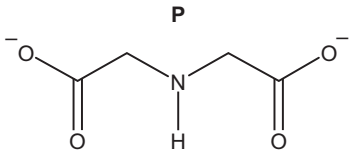
Explain your answer.

Question 1

[1]

(e) The dianion **P** can act as a tridentate ligand.

P



(i) Suggest how **P** can form **three** dative covalent bonds.

Question 1

(ii) 2 moles of dianion **P**, $C_4H_5NO_4^{2-}$, react with 1 mole of aqueous cobalt(III) ions, $[Co(H_2O)_6]^{3+}$ to form 1 mole of complex ion **Q**.

Deduce the formula and charge of **Q**.

Question 1

(f) Table 1.1 shows values for the stability constants, K_{stab}, of some silver(I) complexes.

Table 1.1

complex	value of K_{stab}
$[Ag(CN)_2]^-(aq)$	1.1×10^{18}
$[Ag(NH_3)_2]^+(aq)$	1.2×10^{7}
$[Ag(S_2O_3)_2]^{3-}(aq)$	2.9×10^{13}

(i) Define the stability constant of a complex.

Question 1

(ii) Use the information in Table 1.1 to identify the most stable silver(I) complex.

Explain your answer.

Question 1

Question 1

Question 1

[1]

(g) Sodium sulfite, Na_2SO_3, is used as a food preservative.

A 3.75 g sample of impure Na_2SO_3 is dissolved in distilled water and made up to 250 cm^3 in a volumetric flask.

10.0 cm^3 of this solution requires 18.70 cm^3 of acidified 0.0150 mol dm^{-3} MnO_4^-(aq) to reach the end-point.

The equation for the reaction is shown.

$$2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$$

Calculate the percentage by mass of Na_2SO_3 in the sample.

Question 1

Question 1

[Total: 19]

Solution 1

(a)

Mark scheme

- forms (one or more) stable ions / compounds / oxidation states
- with incomplete / partially filled (3)d orbital(s) / d shell / d sub-shell
- 1

Solution 1

(b)(i)

Mark scheme

- (orbitals) are at the same energy
- 1

(b)(ii)

Mark scheme

- (1s2) 2s2 2p6 3s2 3p6 3d9
- 1

Solution 1

(c)(i)

Mark scheme

H3)4(H2O)2 2+(aq) deep / dark / royal blue

- AND

CuCl4 2–(aq)

- yellow
- 1

Solution 1

(c)(ii) Mark scheme

- M1:
- d orbital(s) of different energy / d-d splitting occurs / d sub-shell splits
- M2:
- electron(s) promoted / excited
- M3:
- light / wavelength / frequency / photon absorbed AND complementary colour seen
- 3

Solution 1

(d)(i)

Mark scheme

- M1: ligand exchange / replacement / substitution / displacement
- M2: $[CuCl_4]^{2-} + 4NH_3 + 2H_2O \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4Cl^-$
- 2

Solution 1

(d)(ii)

Mark scheme

- M1: one correct 3D structure of [Cu(H2O)2(NH3)4]2+
- M2: correct 3D stereoisomer structure of isomer 1/2

(d)(iii)

Mark scheme

- cis isomer AND dipoles do not cancel
- 1

Solution 1

(e)(i)

Mark scheme

- (two) oxygen and (one) nitrogen (can donate) three lone pair(s) of electrons (to the metal ion)
- 1
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Solution 1

(e)(ii)

Mark scheme

C4H5NO4)2 –

- 1

Solution 1

(f)(i)

Mark scheme

- equilibrium constant for the formation of the complex (ion)
- in a solvent / water / solution OR from its constituent ions or molecules
- 1

Solution 1

(f)(ii)

Mark scheme

$Ag(CN)_2^-$(aq) AND largest (value of) Kstab

- 1

Solution 1

(g) Mark scheme

- M1 M2: any two [1], all four [2]
- ▪
- moles MnO4– = 0.015 ×18.70/1000 = 2.805 × 10–4
- ▪
- moles SO32– = 2.805 × 10–4 × 5/2 = 7.0125 × 10–4 (in 10 cm3)
- ▪
- moles SO32– = 1.753 × 10–2 (in 250 cm3)
- ▪

Solution 1

- mass Na2SO3 = 1.753 × 10–2 × 126.1 = 2.21 g
- M3: % purity = 100 × 2.21 / 3.75 = 58.9 – 59.0 % min 2sf
- 3