EXAM PAPERS PRACTICE

Boost your performance and confidence with these topic-based exam questions

Practice questions created by actual examiners and assessment experts

Detailed mark scheme

Suitable for all boards

Designed to test your ability and thoroughly prepare you

Transition metals 2

CHEMISTRY

Mark Schemes

AQA

AS & A LEVEL

Inorganic Chemistry

Mark schemes

1 (a) Ligand: -
atom, ion or molecules which can donate a pair of electrons to a metal ion.

1

co-ordinate bond:- a covalent bond

1

in which both electrons are donate by one atom

1

(b) (i) Two correct complex ions

1

Balanced equation

1

Two correct colours

2

(ii) Complex with a bidentate ligand

1

Balanced equation
NB en *not allowed as a ligand unless structure also given*

1

More molecules/ions formed

1

Increase in entropy

1

more stable complex formed

1
Max 2

(c) ΔE; energy absorbed by electron, ground to excited state (QoL)

1

h; Planck's constant or a constant

1

Change in

Oxidation state

1

Ligand

1

Co-ordination number

Apply list principle to incorrect additional answers

1

[16]

2 (a) Iron

1

Heterogeneous; catalyst in a different phase from that of the reactants

1

Poison; a sulphur compound (allow sulphur)

1

Poison strongly adsorbed onto active sites/ blocked

1

Poison not desorbed or reactants not adsorbed or catalyst surface area reduced

1

(b) Pale green solution 1

Green precipitate formed

1

Insoluble in excess ammonia

1

Equation:

e.g. $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ Species

1

Balance

1

NB Allow equations with H_2O and OH^- if reaction of H_2O with NH_3 also given

Max 4

[9]

3 A **[1]**

4 D **[1]**

5 D **[1]**

6 (a) (i) An atom, ion or molecule which can donate a lone electron pair

1

(ii) A central metal ion/species surrounded by co-ordinately bonded ligands or ion in which co-ordination number exceeds oxidation state

1

(iii) The number of co-ordinate bonds formed to a central metal ion or number of electron pairs donated or donor atoms

1

(b) (i) *Allow the reverse of each substitution*

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

Complex ions

1

Balanced

1

Allow partial substitution

(ii) $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 or $C_2O_4^{2-}$ by Cl^-

1

eg. (iii) $[Co(H_2O)_6]^{2+} + 3C_2O_4^{2-} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$

Complex ions

1

Balanced

1

Allow all substitution except
(i) NH_3 by H_2O
(ii) more than $2Cl^-$ substituted for NH_3 or H_2O

eg. (iv) $[Co(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 by $C_2O_4^{2-}$ and NH_3 or Cl^- by $EDTA^{4-}$

1

(c) (i) $[Fe(H_2O)_6]^{2+}$

1

(ii) $Fe(OH)_2$ or $Fe(OH)_2(H_2O)_x$ where $x = 0$ to 4

1

(iii) Fe^{2+} is oxidised to Fe^{3+} or $Fe(OH)_3$

1

By oxygen in the air

1

[15]

7 (a) A catalyst in the same phase/phase as the reactants

1

(b) (i) A reaction in which a product acts as a catalyst

1

(ii) Mn^{2+} or Mn^{3+}
"Self-catalysing" not allowed

1

(c) (i) $2CO + 2NO \rightarrow 2CO_2 + N_2$

or $4CO + 2NO_2 \rightarrow 4CO_2 + N_2$
C not allowed as a product

1

Reducing agent CO

1

(ii) Pt, Pd or Rh

1

Deposited on a ceramic honeycomb or matrix or mesh or sponge

1

To increase surface area of catalyst

1

(d) (i) Reactants cannot move on surface or products not desorbed or
Active sites blocked

1

(ii) Reactants not brought together or
No increase in reactant concentration on catalyst surface or
Reactants not held long enough for a reaction to occur or
Reactant bonds not weakened

1

[10]

8 D **[1]**

9 B **[1]**

10 D **[1]**

11 D **[1]**

12 B **[1]**

13 D **[1]**

14 A **[1]**

15 A **[1]**

16 C **[1]**

17 D **[1]**

18 C **[1]**

19 D **[1]**

20 D **[1]**

21 (a) (i) Heterogeneous:- In a different phase to reactants **(1)**
Catalyst:- Increases reaction rate **(1)**
Alternative route or route described **(1)**
Lower E_a **(1)**
Unchanged at end of reaction **(1)** Max 4

(ii) Feature:- QoL Variable oxidation states shown by vanadium **(1)**
Equations $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ **(1)**
$2V_2O_4 + O_2 \rightarrow 2V_2O_5$ **(1)**

7

(b) $VO_2^+ + 4H^+ + 3e^- \rightarrow V^{2+}(aq) + 2H_2O$ **(1)**

$Zn \rightarrow Zn^{2+} + 2e^-$ (given)

$2VO_2^+ + 8H^+ + 3Zn \rightarrow 3Zn^{2+} + 2V^{2+}(aq) + 4H_2O$ **(1)**

2

Mol $KMnO_4$ = mv/1000 = 0.0200 × 38.5/1000 = 7.70×10^{-4} **(1)**

Mole ratio MnO_4^- to V(II) = 3:5 deduced

or equation

$5V^{2+} + 3MnO_4^- + 4H^+ \rightarrow 2H_2O + 3Mn^{2+} + 5VO_2^+$ **(2)**

Mol V(II) = $7.70 \times 10^{-4} \times 5/3$ **(1)** = 1.283×10^{-3}

Mass V = $1.283 \times 10^{-3} \times 50.9$ **(1)** = 0.0653 g

% V in sample = 0.06532 × 100/0.160 = 40.8 **(1)**

6

[15]

22 (a) A shared <u>electron</u> pair or a <u>covalent</u> bond **(1)**
Both electrons from one atom **(1)**

OR when a Lewis base reacts with a Lewis acid
Mark points separately

2

(b) *Brønsted-Lowry acid*: A proton or H^+ donor **(1)**

Not H_3O^+

Lewis acid: A lone or electron pair acceptor **(1)**

2

(c) Two atoms or two points of attachment **(1)**
Each donating a lone electron pair **(1)**

OR forms 2 (1) co-ordinate bonds (1)
OR donates two (1) pairs of electrons (1)

2

(d) *Change in co-ordination number*: 6 to 4 **(1)**

Reason for change: chloride ligands are larger than water ligands **(1)**

2

OR greater repulsion between chloride ligands
DO NOT allow chlorine or Cl

(e) Same number **(1)**, and same type of bonds **(1)**, broken and made

2

(f) $ClNH_3CH_2CH_2NH_3Cl$ **(1)**

OR $(NH_3CH_2CH_2NH_3)^{2+}$ $2Cl^-$
Allow $C_2H_{10}N_2Cl_2$ *and* $NH_3ClCH_2CH_2NH_3Cl$

1

[11]

23 (a) High E_a: $S_2O_8^{2-}$ repels I^- **or** both ions negative **(1)**

$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ **(1)**

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ **(1)**

N.B. Ignore additional incorrect equations

Vanadium is a transition element **or** Magnesium is not a transition element **(1)**

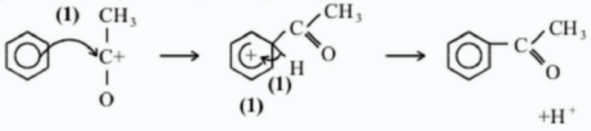
Vanadium has variable oxidation states **(1)**

Magnesium only forms Mg^{2+}, **or** has only one oxidation state **(1)**

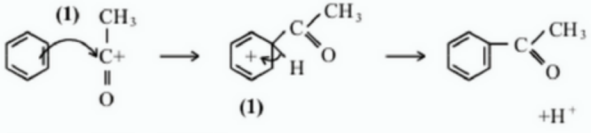
N.B. Score two marks for "Only vanadium has variable oxidation states"

6

(b) $AlCl_3 + Cl\text{-}COCH_3 \rightarrow AlCl_4^- + CH_3CO^+$ **(1)**



or



$H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ **(1)**

Lewis acid: $AlCl_3$ accepts electron pair

N.B. penalise incorrect acyl chloride by one
N.B. penalise chloroethane by two marks i.e. first equation mark, attack on benzene mark

NH_4Cl: Not a catalyst **(1)**

$FeCl_3$: A catalyst **(1)**
has a low energy vacant shell
or has spaces or vacancies in d shell
or has a partially filled d shell
or able to accept an electron pair
or can form $FeCl_4^-$ **(1)**

9

[15]

24 (a) Electron transitions/electrons excitedin d shell **(1)** **o**r d-d transition

Do NOT allow charge transfer

(Energy in) visible range **(1)**

(NOT emits in visible region)

2

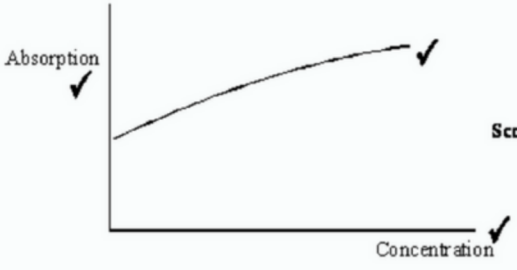
(b) *Change 1*: (Different) oxidation states **(1)**
Change 2 : (Different) ligands **(1)**
Change 3: (Different) co-ordination number **(1)**

Do not allow shape as an answer

3

(c) Add an appropriate (or a given correct) ligand to intensify colour **(1)**
e.g. thiocyanate $(CNS)^-$ or bipyridyl
Make up solutions of known concentration **(1)**
Measure absorption or transmission **(1)**
Plot graph of results or calibration curve **(1)**
Measure absorption of unknown and **(1)**
compare

N.B.: Allow concentration statement if included in graph statement
Allow adsorption but circle the d
Also



Scores 3

5

[10]

25 Linear complex e.g. $[Ag(NH_3)_2]^+$ **(1)**

Tetrahedral complex e.g. $[CoCl_4]^{2-}$ **(1)**

Octahedral complex e.g. $[Fe(H_2NCH_2CH_2NH_2)_3]^{3+}$

Species (1)
Charge (1)

[4]

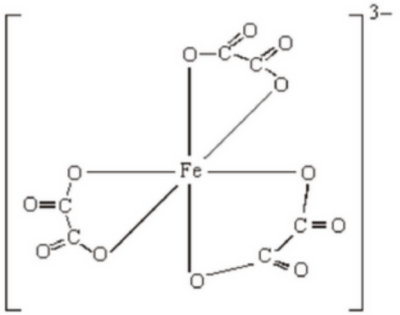
26 D

[1]

27 (a) (i) Two **(1)** lone pair donor / electron pair donor **(1)** atoms
Allow:– forms two co-ordinate bonds **(1)**

NOT atom with two lone pairs

(ii)



Correct ligand structure ***(1)*** (O ‖ C not essential)
penalise any error
Six correct O–Fe bonds ***(1)***
Correct charge ***(1)***
N.B. Penalise the second mark if arrow from Fe shown
N.B. Ignore charges on atoms

5

(b) (Substitution of a monodentate ligand by a) bi or multidentate ligand **(1)** giving a more stable complex **(1)** or with an increase in entropy / disorder or forming a ring / cage complex / structure (crab like)

2

(c) (i) $[AgCl_2]^-$ or $AgCl_2^-$ **(1)**

(ii) Chloride or Cl^- big or large or repel **(1)**

NOT Cl_2 or Cl^+ or Cl

Allow 'chlorine ion'

2

(d) (i) (Both) ions are negative or ions repel or High E_a **(1)**

(ii) *Meaning of the term autocatalytic:* A product of the reaction acts as a catalyst **(1)**

NOT a self catalysing reaction (0)

Catalyst: Mn^{2+} or Mn^{3+} **(1)**

(iii) Mn^{2+} converted into Mn^{n+} or Mn^{2+} oxidised **(1)**
Mn^{n+}/oxidised species then <u>oxidises/reacts with $C_2O_4^{2-}$</u> **(1)**

5

[14]

28 C **[1]**

29 A **[1]**

30 B **[1]**

31 D **[1]**

32 (a) $C_2O_4^{2-}$ or $H_2NCH_2CH_2NH_2$ **(1)**

1

(b) $[AgCl_2]^-$ or $[Ag(CN)_2]^-$ or $[Ag(NH_3)_2]^+$ **(1)**

1

(c) e.g. $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

2

(d) e.g. $[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

2

(e) *Equation:* $[Co(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$ **(1)**
Explanation: More molecules on right hand side **(1)**
Entropy increases **(1)**

3

[9]

33 (a) reactants brought together / increased concentration on surface
or increased collision frequency **(1)**
reactants must be correctly orientated **(1)**
reaction on the surface **(1)**
products desorbed **(1)**
example of a catalysed reaction (not a named process) **(1)**
a suitable catalyst for this reaction **(1)**

penalise incorrect second reactions and catalysts

If absorption too weak reactants not brought together **(1)**
e.g. silver **(1)**
If adsorption too strong products not desorbed **(1)**
e.g. tungsten **(1)**

max 8

(b) Equations:

$Cr_2O_7^{2-} + 14\ H^+ + 6\ Fe^{2+} \rightarrow 6\ Fe^{3+} + 2\ Cr^{3+} + 7\ H_2O$ **(1)**
$Zn + 2\ Fe^{3+} \rightarrow Zn^{2+} + 2\ Fe^{2+}$ **(1)**

Method

Titrate measured volume solution against $K_2Cr_2O_7$ **(1)**

Reduce same volume solution with zinc **(1)**

Filter off excess zinc **(1)**

Titrate total Fe^{n+} using $K_2Cr_2O_7$ **(1)**

Percentage Fe^{3+} = 100 × (titre2 - titre1) / titre 2
or equivalent **(1)**

7

[15]