5.4 QUESTIONS PART 2 MS

1. (a) *Homogeneous* — same phase as reactants **(1)**

Most important mechanistic feature — change of oxidation state **(1)** — 2

(b) (i) $2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-}$ **(1)**

(ii) negative ions repel **(1)**

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

Equation 2 $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$ **(1)** — 4

(c) (i) *Identity of metal 1* — W **(1)**

Reason for low efficiency — adsorption too strong **(1)**

Identity of metal 2 — Ag **(1)**

Reason for low efficiency — adsorption too weak **(1)**

(ii) Ease of adsorption (not too weak) and desorption (not too strong) balance out **(1)**

5

(d) *Catalyst* — Pt <u>or</u> Rh or Pt/Rh **(1)**

Identity of reductant — CO **(1)**

Equation — $2CO + 2NO \rightarrow N_2 + 2CO_2$ **(1)** — 3

[14]

2. (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+} — 1
"Self-catalysing" not allowed

(c) (i) $2CO + 2NO \rightarrow 2CO_2 + N_2$ — 1
or *$4CO + 2NO_2 \rightarrow 4CO_2 + N_2$*
C not allowed as a product

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 — 1
No increase in reactant concentration on catalyst surface or
Reactants not held long enough for a reaction to occur or
Reactant bonds not weakened

[10]

3. (i) Increase the rate of the forward and backwards reactions **(1)**
by an equal amount **(1)**

(ii) *Equation* $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (or other industrial process) **(1)**
Catalyst Iron **(1)** 4

[4]

4. (a) (i) $Fe + 2HCl \rightarrow FeCl_2 + H_2$ (allow ionic formulae)
or $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$ 1

(ii) PV = nRT n = PV/RT (allow either formula but penalise contradiction) 1

$n = \frac{110000 \times 102 \times 10^{-6}}{8.31 \times 298}$ 1

$= 4.53 \times 10^{-3}$ (mol) 1

(answer must have at least 3 sig. figs. Ignore units)

(iii) Moles of iron = $4.5(3) \times 10^{-3}$ mol
(allow conseq on (a)(ii))

(or = $4.2(5) \times 10^{-3}$ if candidate uses given moles of hydrogen) 1
Mass of iron = $4.53 \times 10^{-3} \times 55.8 = 0.253$ g
(mark is for method mass = moles × A_r)
(Mass of iron can be 56) 1

(iv) 0.253 × 100/0.263 = 96.1 % (mark is for answer to 2 sig. figs.) 1
(allow conseq on mass of iron. E.g. = 90% from
$4.2(5) \times 10^{-3}$ moles of H_2 and Fe)

(Do not allow answers greater than or equal to 100%)

(b) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (ignore state symbols) 1
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ 1
$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$ 1

(ii) Moles of dichromate = moles Fe^{2+}/6
(Allow conseq, mark is for method (a)(iii)/6)

$= 4.53 \times 10^{-3}/6 = 7.55 \times 10^{-4}$ 1
Volume of dichromate = moles/concentration
(mark is for this method)

$(= (7.55 \times 10^{-4} \times 1000)/0.0200)$ 1
V = 37.75 (cm^3) 1

(allow 37.7 to 37.8, allow no units but penalise wrong units)

(allow conseq on moles of dichromate)

(if value of 3.63×10^{-3} used answer is 30.2 to 30.3,
otherwise ans = moles Fe^{2+}/0.00012)

(if mole ratio wrong and candidate does not divide by 6,
max score is ONE for volume method)

(iii) ($KMnO_4$) will also oxidise (or react with) Cl^- (or chloride or HCl) 1

[14]

5. (a) (i) NaOH
(or KOH) 1

(ii) +6
(or 6 or +VI or VI) 1

(iii) H_2O_2
(orNa_2O_2 or BaO_2) 1

$[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ 1

(or $[Cr(OH)_6]^{3-} \rightarrow CrO_4^{2-} + 2H_2O + 2H^+ + 3e^-$)

(b) $[Cr(H_2O)_6]^{2+}$ 1

Reducing agent 1

(mark independently)

(c) (i) ethanal (or CH_3CHO) (not CH_3COH) 1

(ii) Ethanoic acid (or correct formula) 1

[8]

6. (a) (i) Orange 1

(ii) Red-violet/ruby/violet/ green 1

(ii) Purple 1

(b) (i) MnO_4^-/Mn^{2+} has a more positive $E^\ominus$ value than Cl_2/Cl^- 1

or data used

and will oxidise Cl^- or change Cl^- to Cl_2 1

Allow converse answers

(ii) NO_3^-/HNO_2 has a more positive $E^\ominus$ value than Fe^{3+}/Fe^{2+} 1

or data used

and will oxidise Fe^{2+} or change Fe^{2+} to Fe^{3+} 1

[7]

7. (a) *Metal 1* W, Zr, Nb, Mo, Hf or Ta **(1)**

Explanation Adsorb too strongly **(1)**

Products not desorbed or no movement or catalyst surface **(1)**

Metal 2 Ag, or Au **(1)**

Explanation Adsorbs too weakly **(1)**

Reactants not brought together or no increase in concentration of reactants on surface **(1)** 6

(b) (i) Catalyst provides an alternative route **(1)**

with a lower activation energy **(1)**

(ii)

Esterification	$I^- + S_2O_8^{2-}$	$SO_2 + O_2$	O_3 decomposition	**(1)**
H_2SO_4/acid	Fe^{2+}/Fe^{3+}	NO	$Cl\cdot$	**(1)**

4

[10]

8. (a) gains electrons **(1)** 1

(b) V_2O_5 **(1)**

$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$ **(1)** 2

(c) mix reagents, time some observation e.g. disappearance of colour **(1)**
repeat with added Mn^{2+} **(1)**
shorter time shows catalysis **(1)** 3

(d) (i) H_2O_2 **(1)** NaOH **(1)**

(ii)

$KMnO_4$ [1] dil H_2SO_4 [1] $K_2Cr_2O_7$ O_2, air	Cl_2 [2]	K_2S_2O <u>or</u> H_2O_2 [2]

(iii) Zn **(1)** HCl **(1)**
or dil H_2SO_4 6

[12]

9. (a) (i) Alternative / different route / mechanism **(1)**
Lower activation energy / Ea **(1)**

Do not allow Surface effect or Change Ox.St or no change in mass/state

(ii) Variable oxidation states **(1)**
Not incomplete d – shells

(iii) $S_2O_8^{2-}$ OR $C_2O_4^{2-}/MnO_4^-$ or NaK Tartrate/H_2O_2 **(1)**

Fe^{2+}/Fe^{3+} Mn^{2+} Co^{2+}/Co^{3+} **(1)**

Reagents with correct names or formulae

Allow the catalysts if reaction essentially correct

Do not allow metallic elements 5

(b) (i) Reactants/chemicals in a different state/phase (to the catalyst) **(1)**
Or More than one state/phase

(ii) Surface adsorption/adsorption (onto the catalyst) **(1)**

Penalise a<u>b</u>sorption

Reaction/equivalent (on surface) **(1)**

Allow correct statement e.g. bonds weakened, conc. increased

(Products) desorbed (from surface) **(1)**

Steps must be in the correct order 4

(c) (i) <u>Iron</u> Not Fe^{2+} or Fe^{3+} **(1)**

(ii) S; H_2S; CO; CO_2 or H_2O but not ‘sulphide’ **(1)**
<u>Blocks</u> active sites or <u>not desorbed</u> **(1)**

i.e. need a clear indication of irreversibility

Mark explanation separately 3

[12]

10. (a) (i) +6 **or** 6 **or** 6+ **not** Cr^{6+} **(1)** — 1

(ii) $\underline{1}\ Cr^{3+} + \underline{8}\ OH^- \longrightarrow \underline{1}\ CrO_4^{2-} + \underline{4}\ H_2O + \underline{3}\ e^-$

($\underline{1}$ need not be shown)

allow multiples **(1)** — 1

(b) (i) $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ allow multiples **(1)** — 1

(ii) yellow **(1)**

orange **(1)** — 2

mark these colours independently

[12]

11. $FeSO_4/SO_2/H_2O_2$/Fe/stated aldehyde 1^y or 2^y ROH **(1)**

acid <u>or</u> dil H_2SO_4 (above) **(1)**

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

<u>or</u> two half-equations

Zn **(1)** HCl <u>or</u> dil H_2SO_4 **(1)**

absence of air **(1)**

$Cr_2O_7^{2-} + 14H^+ + 4Zn \rightarrow 2Cr^{2+} + 7H_2O + 4Zn^{2+}$ **(2)**

<u>or</u> two half-equations — 9

[9]

12. (a) If adsorption too weak reactants not brought together **(1)**
If adsorption too strong products not desorbed OR
reactants cannot move on surface of catalyst **(1)** — 2

(b) Reactants need to be correctly orientated **(1)** — 1

(c) (i) The reaction has a high activation energy **(1)**

(ii) $SO_2 + NO_2 \rightarrow SO_3 + NO$ **(1)**

$2NO + O_2 \rightarrow 2NO_2$ **(1)** — 3

[6]

13. (a) (i) speeds rate **(1)**

unchanged at end **(1)**

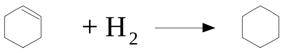
new route **(1)**
<u>or</u> lower AE

(ii) Same phase (state) **(1)**

(iii) +1 **(1)**

4 **(1)**

(iv) lone pair **(1)** — 7

(b) (i) 

or $C_6H_{10} + H_2 \rightarrow C_6H_{12}$

(ii) *Reagent(s)* Br_2 or $KMnO_4$ **(1)**

Observation(s) no change **(1)**

(iii) Variable oxidation state **(1)** 4

[11]

14. (a) e.g. Homogeneous: catalyst in same phase **(1)** as reactant **(1)** 2

(b) Minimum energy **(1)**
For a reaction to occur **(1)** 2

(c) (i) *Homogeneous or heterogeneous* hetrogeneous **(1)**
Explanation of Catalysis favourable orientations, weakening bonds, increased surface concentrations etc.
ANY TWO **(2)**

[Or the alternative
Vanadium catalyst changes oxidation state **(1)**
$SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$
$2V_2O_4 + O_2 \rightarrow 2V_2O_5$ **(1)**]

(ii) homogeneous or heterogeneous **(1)**
lock and key, favourable orientations,
weakening bonds, increased concentrations etc. ANY TWO **(2)** 6

(d) *Meausre 1* increase surface area of catalyst **(1)**
Meausre 2 remove catalyst poisons from reactants **(1)** 2

[12]

15. (a) Dilute sulphuric acid **(1)**

Colourless to pink or purple or red **(1)** 2

(b) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ **(1)**

$MnO_4^- + 8^{H+} 5e^- \rightarrow Mn^{2+} + 4H_2O$ **(1)**

$5 Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5 Fe^{3+} + Mn^{2+} + 4H_2O$ **(1)** 3

(c) Mol $KMnO_4$ = 25 × 0·02/1000 $= 5 \times 10^{-4}$ **(1)**

Mol $Fe^{2+} = 5 \times 5 \times 10^{-4}$ $= 2{\cdot}5 \times 10^{-3}$ **(1)**

Mr compound = 392 **(1)**

Mass = mol × Mr = $2{\cdot}5 \times 10^{-3} \times 392$ = 0·98g **(1)**

4

[9]

16. (a) (i) $[Cu(H_2O)_6]^{2+}$ **(1)** 1

(ii) $[Cr(H_2O)_6]^{3+}$ **(1)** 1

(b) (i) MO_4^- **(1)** 1

(ii) $Cr_2O_7^{2-}$ **(1)** 1

(c) (i) purple solution / manganate(VII) in burette **-** permanganate, MnO_4^- acceptable **(1)**

to flask add dilute H_2SO_4 / (strong) acid / H^+ **(1)**

not HCl, HNO_3, CH_3COOH, **nor** H_2SO_4

pipette known quantity of ethanedioate into conical flask **(1)**

warm (≥ 50°C if temperature specified) **(1)**

add manganate(VII) from burette until first pink/purple colour **(1)** max 5

repeat until concordant results **(1)**

(*) if chemicals reversed mark as appropriate

(ii) $2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$ **(1)**

all correct ions

balanced **(1)** 2

(e) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ ($3d^6 4s^2$ can be reversed) **(1)** 1

(ii) lose two $4s^2$ elections **(1)**

can lose another to give half full shell **(1)** 2

[14]

17. (a) homogeneous = same phase

heterogeneous = different phase

applies to <u>reactants</u> and <u>catalyst</u> 1

(b) to maximize surface area **(1)**

and minimise cost **(1)** 2

(c) reaction between ions of same charge has high E_a **(1)**

$2\ Fe^{3+}\ (aq) + 21^-\ (aq) \rightarrow 1_2\ (aq) + 2Fe^{2+}\ (aq)$ **(1)**

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

if Fe^{2+} ions are added, oxidation gives Fe^{3+} and vice versa **(1)** 4

(d) (i) <u>surface adsorption</u> OR <u>active sites</u> **(1)**

bond weakening OR favourable orientations

OR increase in surface concentration (any 2) [2]

(ii) e.g $N_2\ (g) + 3H_2\ (g) \rightarrow 2NH_3\ (g)$

e.g $2SO_2\ (g) + O_2\ (g) \rightarrow 2SO_3\ (g)$

OR any other suitable examples [2] 5

[12]

18. (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

[6]

19. (a) (i) $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

all species correct **(1)** balance **(1)**

Mn^{2+} is catalyst **(1)**

none present at first ∴ slow <u>or</u> more present later ∴ faster **(1)**

autocatalysis <u>or</u> different route of lower AE **(1)**

(ii) 2 anions reacting together **(1)** }
Fe^{2+} catalyst or lowers AE **(1)** }
because variable oxidation state **(1)** }
$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ **(1)** }
$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ **(1)** }

Mg no variable O.S. or higher O.S.

or Mg^{2+} can't be oxidised/reduced **(1)** 10

(b) moles MnO_4^- = $\frac{27.5 \times 0.02}{1000}$ = 5.5×10^{-4}

(1)

moles Mo = $\frac{5}{3} \times 5.5 \times 10^{-4}$

(1) wrong ratio = max 2 (marks 1 & 3)

g Mo = $96 \times \frac{5}{3} \times 5.5 \times 10^{-4}$

(1)

% Mo = $\frac{96 \times 5 \times 5.5 \times 10^{-4}}{3 \times 0.33} \times 10^2$ **(1)**

= 26.7 **(1)**

26.6 if Mo = 95.9 used 5

[15]

20. (a) effect on reaction rate: catalyst provides an alternative reaction route.; 1
with a lower E_a; 1
more molecules able to react or rate increased; 1

equilibrium: forward and backward rates changes by the same amount; 1
hence concentration of reactants and products constant or yield unchanged; 1

(b) heterogeneous: catalyst in a different phase or state to that of the reactants; 1

active site: place where reactants adsorbed or attached or bond etc.; 1
reaction occurs or an explanation of what happens; 1
(allow absorbed)

reasons: large surface area; 1
reduce cost or amount of catalyst; 1

catalyst poison: lead adsorbed; 1
lead not desorbed or site blocked; 1
(lead adsorbed irreversibly scores both of these marks)

(c) reaction slow as: both ions negatively charged or ions repel; 1

$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ Species; 1
Balanced; 1

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Species ; 1
Balanced; 1

[17]

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)** 3 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. 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

[5]

23. (a) (Initially slow) because reaction is between two negative ions 1

(or between two negative reactants or two negative species)

Which repel each other 1

Then Mn^{2+} (or Mn^{3+}) (ions) are formed acting as an autocatalyst (QOL mark) 1

(or answer such as Mn^{2+} ions formed in the reaction act as a catalyst)

$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 4CO_2$ 1

$MnO_4^- + 4Mn^{2+} + 8H^+ \rightarrow 5Mn^{3+} + 4H_2O$ 1

$C_2O_4^{2-} + 2Mn^{3+} \rightarrow 2Mn^{2+} + 2CO_2$ 1

(Note these equations may gain credit if they have spectator ions and/or be written as half equations)

(b) Active sites are where reactants are adsorbed onto a catalyst surface 1

(or bind or react on a catalyst surface)

(do not allow absorbed)

(Number of active sites increases if) surface area is increased 1

(or catalyst spread thinly)

(or on honeycomb)

(or powdered)

(or decreased particle size)

Active sites blocked by another species (or poison) 1

(or species adsorbed more strongly)

(or species adsorbed irreversibly)

(or species not desorbed)

(Note, credit any answer that implies blocked but not just active site 'poisoned')

Sulphur (compounds) in Haber process 1

(or lead in a catalytic converter)

(Note do not allow enzymes unless immobilised)

[10]

24. (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]

25. CrO_7^{2-} + 6Fe^{2+} + 14H^+ $\rightarrow$ 2Cr^{3+} + 6Fe^{3+} 7H_2O **(2)**
<u>or</u> two half equations, scores **[2]** if electrons cancel
(1) if electrons don't cancel

moles Fe^{2+} = $\frac{24.0 \times 0.1}{1000}$ **(1)** = 2.4 × 10^{-3}

moles $Cr_2O_7^{2-}$ = $\frac{2.4 \times 10^{-3}}{6}$ **(1)** = 0.4 × 10^{-3}

g $(NH_4)_2Cr_2O_7$ = 0.4 × 10^{-3} × 252 **(1)** = 0.101 (g) **(1)**

g NH_4Cl = 0.223 – 0.101 **(1)** = 0.122 g **(1)**

mole ratio $(NH_4)_2Cr_2O_7$: NH_4Cl

= $\frac{0.101}{252}$: $\frac{0.122}{53.5}$ **(1)**

<u>or</u> 4 × 10^{-4}

= 1 : 5.7 (5.69 – 5.71) <u>or</u> 0.176 (0.175) **(1)**

[10]

26. (a) Plan 5 marks

known mass or weight **(1)**

H_2O **(1)**

dil H_2SO_4 **(1)** (scores 2 if no H_2O previously)

titrate or $Cr_2O_7^{2-}$ in burette **(1)**

indicator needed **(1)**

Calc^n 3 marks

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

calc moles $Cr_2O_7^{2-}$, moles Fe^{2+} = 6 × moles $Cr_2O_7^{2-}$ **(1)**

g Fe^{2+} = moles Fe^{2+} × Ar(or 56)

÷ by starting mass, × 100 = % **(1)** 8

(b) (i) V_2O_5 catalyst **(1)**

alternative route or V changes oxidation state

or lower activation energy **(1)**

$V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ **(1)**

($2VO_2$) **or in words**

$V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$ **(1)**

(ii) Mn^{2+} ✓ catalyst **(1)**

none or little present initially ∴ slow or 2 negative ions reacting **(1)**

more as reaction proceeds ∴ faster **(1)**

autocatalysis **(1)**

or explanation of Max 7

[15]

27. (a) Ag or Au or Sc adsorb too weakly **(1)**

A consequence of weak adsorption

reactants not brought together on the surface
no increase in reactant concentration on surface
bonds not weakened
correct orientation on surface not achieved **(1)**

W, Zr, Nb, Mo, Hf or Ta adsorb too strongly **(1)**

A consequence of strong adsorption
products not desorbed
active sites blocked
reactants unable to move on catalyst surface **(1)** 4

(b) Powder has a much greater surface area **(1)**
Reduces amount of expensive catalyst needed **(1)**
Makes it easier to remove spent catalyst from reactor **(1)**
Increases supply of reactant to catalyst surface or increased collisions with catalyst **(1)**
Makes reaction faster as surface area greater **(1)**
Makes it easier to remove product from catalyst surface **(1)** Max 4

(c) A process with the appropriate catalyst **(1)**
The appropriate catalyst poison **(1)**
Blocks active sites or reduces surface area for reaction **(1)**
Poison firmly held or irreversibly adsorbed or not released **(1)** 4

(d) Both ions are negatively charged or same charge **(1)**
Fe^{2+} is converted to Fe^{3+} by the persulphate ion **(1)**
Fe^{3+} then reacts with iodide ions to form iodine. **(1)** 3

[15]

28. (a) (i) *observations*: $\rightarrow$ <u>not</u> ppt green **(1)** $\rightarrow$ blue **(1)**

explanation: reduction **(1)** to Cr (III) <u>or</u> $[CrCl_2(H_2O)_4]$+ or Cr^{3+} **(1)**

to Cr(II) or $[CrH_2O)_6]^{2+}$ <u>or</u> Cr^{2+} **(1)**

(ii) *observations*: $\rightarrow$ blue **(1)** $\rightarrow$ green **(1)** $\rightarrow$ violet **(1)**

explanation: reduction **(1)** to V(IV), V(III),
V(II) or VO^{2+}, V^{3+}, V^{2+} **(1)** 10

(b) (i) same phase **(1)** speeds rate **(1)** new route **(1)** of lower AE **(1)**

unchanged at end **(1)**

TMs use variable oxid^n states **(1)**

example: Fe^{2+}/Fe^{3+} in $S_2O_8^{2-}/I^-$ rn **(1)** <u>or</u>
Mn 2+ in $MnO_4^-/C_2O_4^{2-}$

mechanism: $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$ or MnO_4^- oxidises

$Fe^{3+} + I^- \rightarrow Fe^{2+} + ½ I_2$ <u>or</u> in words **(1)**
or $Mn^{2+} \rightarrow Mn^{3+}$

$Mn^{3+} + C_2O_4^{2-} \rightarrow CO_2$
$+Mn^{2+}$

(ii) reagents mixed with and without Mn^{2+} **(1)**

(must be correct if stated, not MnO_4^-)

time taken for stated observation **(1)**

correct observation e.g starch $\rightarrow$ black colorimeter,
brown colour **(1)**

time shorter if Mn^{2+} catalyses **(1)** 12

(c) (i) $V_2O_5 + SO_2 \rightarrow V_2O_4$ (<u>or</u> $2VO_2$) + SO_3 **(1)**

(ii) moles MnO_4^- $= \dfrac{25 \times \cdot 02}{1000} = 5 \times 10^{-4}$ **(1)**

moles VO^{2+} = <u>5</u> × 5 × 10^{-4} **(1)** (2·5 × 10^{-3})

= moles VO_2 **(1)**

mass VO_2 = <u>83</u> × 2·5 × 10^{-3} **(1)**

(1)

% VO_2 $= \dfrac{83 \times 2\cdot5 \times 10^{-3}}{0\cdot3} \times 100$ **(1)**

= <u>69·2</u> **(1)** 8

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