| Question | | Expected answers | Marks |
|---|---|---|---|
| 1 | (a) | Correct oxidation states for **each** atom i.e. Ca = +2, C = +4 and O = -2 (1);<br>Oxidation numbers do not change during the reaction / no electron transfer during reaction (1) | 2 |
| | (b) | $MgCO_3$ decomposition easier than $CaCO_3$ / higher decomposition temperature with $CaCO_3$ / ora (1);<br><br>$Mg^{2+}$ higher charge density than $Ca^{2+}$ / both have the same charge but $Mg^{2+}$ has a smaller ionic radius (1);<br><br>So $Mg^{2+}$ will polarise $CO_3^{2-}$ more than $Ca^{2+}$ can / more distortion of the $CO_3^{2-}$ electron cloud by $Mg^{2+}$ (1) | 3 |
| | (c) | $\Delta H =$ +1207 +(-635) + (-393) / correct energy cycle drawn / $\Delta H_f$product – $\Delta H_f$ reactants (1);<br><br>$\Delta H =$ +179 (kJ $mol^{-1}$)(1) | 2 |
| | (d) | $Mg^{2+}$ + $O^{2-}$ → MgO (1);<br>(3916 kJ of) energy is released (1);<br><br>when one mole of **solid** magnesium oxide is made from its constituent **gaseous** ions (1) | 3 |
| | (e) (i) | Enthalpy change of atomisation (of oxygen) (1) | 1 |
| | (ii) | **Any two from**<br>$Mg^{+}$ has one more proton than electrons / same number of protons but one fewer electron (1);<br><br>Electron is lost from a particle that carries an overall positive charge (rather than being neutral) (1);<br><br>So (outer) electron more firmly attracted to the nucleus (1) | 2 |
| | (iii) | Correct energy level diagram labelled with correct formulae / correct cycle labelled with correct formulae (1);<br><br>**Any two from**<br><br>Correct state symbols (1);<br><br>Correct energy values shown in the Born-Haber cycle (1)<br><br>Correct labels for the enthalpy changes (1)<br><br>**And**<br><br>Lattice enthalpy = -735 +(-1445) + (-150) + (-878) + 141 + (-247) + (-602) (1) | 4 |
| | (f) | Furnace lining / aw (1) | 1 |
| | | | **Total = 18** |

| Question | | | Expected answers | Marks |
|---|---|---|---|---|
| 2 | (a) | | Have variable oxidation states / aw (1);<br><br>(Elements or compounds are) often catalysts (1) | 2 |
| | (b) | (i) | $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ /<br>$[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s) + 6H_2O(l)$ /<br>$[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(H_2O)_4(s) + 2H_2O(l)$ | 1 |
| | (b) | (ii) | Colorimeter needs a clear solution / precipitate will interfere with the passage of light / precipitate may absorb light / colorimeter has been set up to measure the concentration of just the complex ion (1) | 1 |
| | (c) | | Points plotted correctly (1);<br>Two **straight** lines of best fit that intersect (1) | 2 |
| | (d) | (i) | 0.0025 (1) | 1 |
| | | (ii) | 10 ($cm^3$) | 1 |
| | | (iii) | Answer to part (ii) x $10^{-3}$ / 0.010 (1) | 1 |
| | | (iv) | x = 4 and y = 2 (1) | 1 |
| | (e) | (i) | Has a lone pair / it is an electron pair donor (1) | 1 |
| | | (ii) | Lone pair in the ammonia ligand is more like a bond (pair) / ammonia ligand has four bond (pairs) (1);<br>So equal repulsion between all four electron pairs or bonds with the ligand / extra repulsion due to presence of lone-pair in ammonia / aw (1) | 2 |
| | (f) | (i) | $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ /<br>$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$ /<br>$Cu^{2+} + 4HCl \rightarrow CuCl_4^{2-} + 4H^+$ | 1 |
| | | (ii) | Tetrahedral shape with either wedges or correct bond angles / square planar shape (1) | 1 |
| | | | | **Total = 15** |

1 (a) Diagram to show

Cu in $Cu^{2+}$ (1)

1 mol $dm^{-3}$ solution for $Cu^{2+}$ (1)

298K (1)

salt bridge (1)

named reference electrode, if hydrogen used, must show $H^+$ and $H_2$ (1)

measure voltage, diagram must show complete circuit including voltmeter (1)

comment on how SEP relates to voltage measured/ SEP of hydrogen is 0 (1)

[6max]

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$/ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ (1)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (1)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ (1) [3]

(c) $Cu^{2+}$ coloured because

has vacant d-orbital (1)

(colour due to) electron promotion/ excitation (1)

**energy** is absorbed (1)

in visible part of spectrum (1)

(1)

colour seen is complementary or described (1)

$Cu^+$ not coloured because has a **full** d-subshell (1) [5max]

QWC: correct use of two of the terms electron promotion/excitation, d-orbital, complementary colour(1) [1]

[Total: 15]

| | | | |
|---|---|---|---|
| 2 | (a)(i) | (+)3/ 3+/III (1) | [1] |
| | (ii) | 3D sketch to show | |
| | | tetrahedral (1) | |
| | | square planar (1) | [2] |
| | (iii) | purple (1) | |
| | | green absorbed/ blue and red reflected (1) | [2] |
| | (b)(i) | has a lone/unbonded pair (1) | |
| | | that it donates to a metal (ion)/ that it donates to a central ion/ that it uses to form a dative covalent bond with a metal (1) | [2] |
| | (ii) | ligand that can donate two lone pairs/ that can form two bonds (1) | [1] |
| | (c)(i) | mirror image drawn (1) | [1] |
| | (ii) | optical (1) | |
| | | **non-superimposable** mirror images/ cannot be superimposed (1) | [2] |

[Total: 11]

2

3 (a) SEP used to explain feasibility eg more negative releases electrons/ use of SEP to explain which equation is reversed and then added/ cell potential is + 0.37(V) (1) [1]

(b) involves both oxidation and reduction (1)

of the same **species**/ use of $Cu^+$ or named example (1) [2]

(c) making into solids/ insoluble compounds/ forming complexes NOT named compound (1) [1]

(d)(i) formula CuI/ $Cu_2I_2$ (1)

equation complete and balanced (1) [2]

(ii) blue (solution) at start (1)

white solid is CuI/ copper iodide (1)

iodine is brown (1) [3]

(e) any sensible use of copper as metal and a valid reason for its use in this case

examples include: electrical wiring because it conducts electricity/is ductile
pans because it conducts heat
water pipes because it does not corrode/is not poisonous/ can be bent NOT conducts heat
decorative purposes because it does not corrode/ because it corrodes to attractive colour (1) [1]

[Total: 10]

4 (a)(i) $2 \times 10^{-3}$ (1) [1]

(ii) $6 \times 10^{-3}$ (1) [1]

(iii) 3 ecf possible from (i) and (ii) [1]

(iv) 1 x 3 x 2 = 3 x change in oxidation state of manganese/ evidence of calculation (1)

final oxidation state of manganese = +4 (1) ecf possible

answer alone = 1 [2]

(b) not oxidation/reduction/redox/ statement is not valid BUT must have attempt at explanation (1)

yellow is $CrO_4^{2-}$/ chromate (1)

equilibrium is $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$ / other correctly balanced equations(1)

chromate is in oxidation state 6 (1)

comment on movement of equilibrium with change in pH (1) [4max]

[Total: 9]

1. (a) (i) $Br^-(aq)$ 1st order ✓
[$Br^-(aq)$] triples rate triples ✓

[2]

$H^+(aq)$ 2nd order ✓
[$H^+(aq)$] doubles rate quadruples ✓

[2]

$BrO_3^-(aq)$ 1st order ✓
[$BrO_3^-(aq)$] doubles rate doubles ✓

[2]

(ii) rate = $k[Br^-(aq)]\,[H^+(aq)]^2\,[BrO_3^-(aq)]$ ✓ (state symbols **not** needed)

[1]

(iii)

$$k = \frac{\text{rate}}{[Br^-(aq)]\,[H^+(aq)]^2\,[BrO_3^-(aq)]} = \frac{1.2 \times 10^{-3}}{0.1 \times 0.1^2 \times 0.1} ✓ =$$

rate constant, $k$:= 12 ✓ units: $dm^9\ mol^{-3}\ s^{-1}$ ✓

*(0.0833 would score 1 mark)*

[3]

(b) (i) slowest step✓

[1]

(ii) rate equation shows reaction is 1st order wrt HBr and 1st order wrt $O_2$ ✓
which corresponds to molecules in step 1 ✓

[2]

(iii) $4HBr + O_2 \longrightarrow 2Br_2 + 2H_2O$ ✓

[1]

[Total: 14]

**2.** **(a)** decrease temperature ✓ exothermic direction ✓
increase pressure ✓ favours side with fewer molecules✓

[4]

**(b)** **(i)** The contribution of a gas to the pressure in a gas mixture / mole fraction x total pressure ✓

[1]

**(ii)**

$$K_p = \frac{p\,COCl_2(g)}{p\,CO(g) \times p\,Cl_2(g)}$$ ✓✓

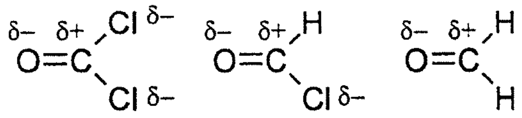
If any [ ] then only ✓ for $K_p$ expression
If upside down with **no** concentration terms [ ], ✓ only

$$K_p = \frac{4.13 \times 10^{-5}}{2.5 \times 10^{-6} \times 2.5 \times 10^{-6}} = 6.6 \times 10^{6}$$ ✓ $Pa^{-1}$

If expression is upside down, then answer consequentially is $1.51 \times 10^{-7}$.

[3]

**(c)** **(i)**




**A** **B**

C=O dipole ✓; δ– on chlorines ✓

*C=O dipole shown correctly on one structure without any contradiction scores 1 mark*

[2]

**(ii)** **A** has 2 δ- / **A** has 2 electronegative atoms / **A** has more electronegative elements than **B** ✓

$COCl_2$ is symmetrical / **A** is **not** symmetrical ✓

dipoles cancel in $COCl_2$ ✓

3 marking points gives [2] max

**(iii)** $COCl_2 + 2H_2O \longrightarrow H_2CO_3 + 2HCl$ ✓✓

OR

$COCl_2 + H_2O \longrightarrow CO_2 + 2HCl$ ✓✓

OR

$COCl_2 + H_2O \longrightarrow O{=}COHCl + HCl$ ✓

[2]

[Total: 14]

3. (a) (i) $H_2 + Cl_2 \longrightarrow 2HCl$ ✓

[1]

(ii) $C_6H_{14} + Cl_2 \longrightarrow C_6H_{13}Cl + HCl$ ✓

[1]

(b) (i) moles HCl = 8 x 15 = 120 mol ✓

volume HCl(g) = 120 x 24 = 2880 ($dm^3$) ✓

[2]

(ii) solution must be diluted by 8.00/0.0200 = 400 times ✓

To 2.50 $cm^3$ of 8.00 mol $dm^{-3}$ HCl✓ add sufficient water to make 1 $dm^3$ of solution.

[2]

(iii) pH= –log[$H^+$] ✓ = 1.70 ✓

[2]

(c) (i) Final pH is approx 11 / equivalence point <7 ✓

[1]

(ii) volume of $NH_3$(aq) that reacts is 15 $cm^3$ ✓

amount of HCl used = 0.0200 x 20.00/1000 = 4 x $10^{-4}$

concentration of $NH_3$(aq) = 4 x $10^{-4}$ x 1000/15 = 0.0267 mol $dm^{-3}$ ✓

[2]

(iii) chlorophenol red ✓

pH range coincides with pH change **during sharp rise** OR pH 4-7 /

coincides with equivalence point ✓

[2]

[Total: 13]

4. (a) A solution that minimises changes in pH (after addition of acid/alkali) ✓

equilibrium: $HCOOH \rightleftharpoons HCOO^- + H^+$

/ HCOOH and $HCOO^-$ / weak acid and its conjugate base ✓

HCOOH reacts with added alkali / $HCOOH + OH^- \longrightarrow H_2O + COO^-$/

added alkali reacts with $H^+$ / $H^+ + OH^- \longrightarrow H_2O$✓

$\longrightarrow HCOO^-$ / Equilibrium moves to right (to counteract change) ✓

$HCOO^-$ reacts with added acid or $H^+$ ✓

$\longrightarrow$ HCOOH / Equilibrium moves to left (to counteract change) ✓

[6]

*qwc: communicates in terms of relevant equilibrium* ✓ [1]

(b) For a buffer, $K_a = [H^+] \times [HCOO^-]/[HCOOH]$ ✓

$[H^+] = K_a \times [HCOOH]/[HCOO^-] = 1.6 \times 10^{-4} \times 1/2.5 = 6.4 \times 10^{-5}$ mol dm$^{-3}$✓

$pH = -\log[H^+] = -\log(6.4 \times 10^{-5}) = 4.19 / 4.2$ ✓

OR

$pH = pK_a - \log [HCOOH]/[HCOO^-]$ ✓

$pK_a = 3.8$ ✓

$pH = 3.8 + 0.4 = 4.2$ ✓

*NOTES*

3.19 worth ✓✓ (incorrect power of 10)

3.4 worth ✓✓ (use of $[HCOOH]/[HCOO^-]$)

[3]

[Total: 10]