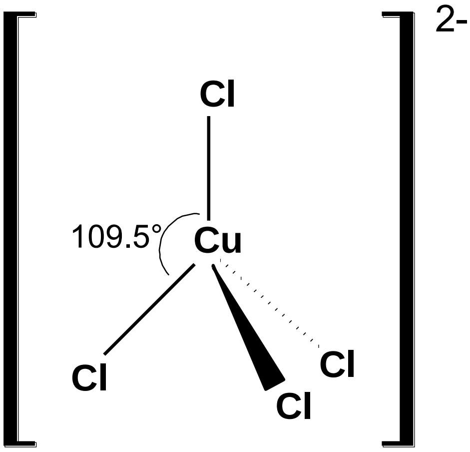
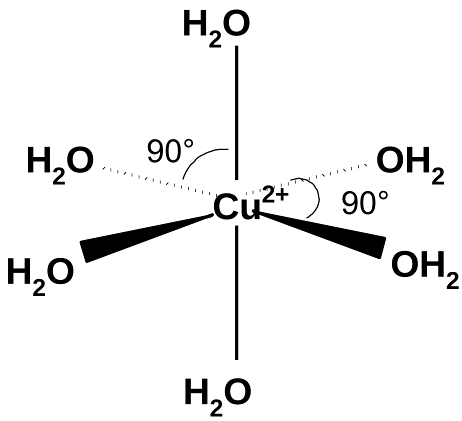
CH5

SECTION A

1. (a) (i) Species with lone pair that can bond to a metal atom/ion (1) [1]

(ii) Must clearly show which atoms are bonded and the 3D structure
1 mark each (2) [2]





(iii) Ligands cause d-orbitals to split into three lower and two higher (1)
Electrons move from lower level to higher level by absorbing some frequencies (1)
Light not absorbed gives colour seen (1) [3]

(iv) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ (1) Royal blue (1) [2]

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(b) (i) $K_p = \frac{P_{PCl3}P_{Cl2}}{P_{PCl5}}$ do not accept if [ ] included [1]

(ii) I. 1.3×10^5 (Pa) [1]

II. $P_{PCl5} = 3.0 \times 10^5 - 1.3 \times 10^5 = 1.7 \times 10^5$ (1) (ecf from part I)

$K_p = (1.3 \times 10^5 \times 1.3 \times 10^5) / 1.7 \times 10^5 = 9.9 \times 10^4$ (1)

Pa (1) [3]

III. Endothermic as equilibrium shifts to products when temperature increases [1]

(c) $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ OR

$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ (1)

Silicon has available empty d-orbitals whilst carbon does not /
Silicon can expand its octet whilst carbon cannot (1) [2]

Total [16]

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2. (a) $2 \times (0) + 3 \times (-394) - (-826) - 3 \times \Delta H^{\theta}_{f}(CO) = -23$ (1)

$2 \times (\Delta H^{\theta}_{f}(Fe)) + 3 \times (\Delta H^{\theta}_{f}(CO_2)) - (\Delta H^{\theta}_{f}(Fe_2O_3)) - 3 \times \Delta H^{\theta}_{f}(CO) = -23$ (1)

$-1182 + 826 + 23 = 3 \times \Delta H^{\theta}_{f}(CO)$

$-333 = 3 \times \Delta H^{\theta}_{f}(CO)$

$-111\ kJ\ mol^{-1} = \Delta H^{\theta}_{f}(CO)$ (1) [3]

(b) Gases have higher entropies than solids as the molecules have a greater degree of freedom / disorder [1]

(c) (i) $\Delta G = \Delta H - T\,\Delta S = -23 - (298 \times 9/1000)$ (1)

$= -25.7\ kJ\ mol^{-1}$ (1) [2]

(ii) A reaction is feasible when ΔG is negative (1)

No temperature exists where ΔG is positive / ΔG is negative at all temperatures (1) [2]

(iii) Higher temperature used to increase rate of reaction [1]

Total [9]

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3. (a) +1 occurs due to inert pair of s-electrons (1)
Inert pair effect becomes more significant down the group (1) [2]

(b) (i)

B	H	
$\frac{78.14}{10.8}$	$\frac{21.86}{1.01}$	
7.235	21.644	(1)
1	3	

Empirical formula = BH_3 (1) [2]

(ii) Number of moles = 1/22.4 = 4.46×10^{-2} moles (1)

$M_r = 1.232 / 4.46 \times 10^{-2} = 27.6$ (1)

Molecular formula = B_2H_6 (1) [3]

(c) Outer/valence shell of electrons is not full / does not have an octet [1]

(d) $B_5H_9 + 15H_2O \rightarrow 5H_3BO_3 + 12H_2$ [1]

(e) The compound is less stable than the elements [1]

(f) Any 3 from 4 points for (1) each

All atoms the same in graphite / BN alternate in boron nitride (1)
Atoms in layer of BN lie above each other but are not in graphite (1)
B—N bonds are polarised (or indicated dipole) but graphite is non-polar (1)
p-electrons in BN are localised but in graphite are delocalised (1) [3]

QWC Organisation of information clearly and coherently; use of specialist vocabulary where appropriate [1]

(g) Mass number = 7 Atomic number =3 [1]

Total [15]

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SECTION B

4. (a) Filtration [1]

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

(c) (i) Carbon O.S. at start = +3; Carbon O. S. at end = +4 [1]

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

(d) Colour change of manganate(VII) is used to indicate the change [1]

(e) Volume of manganate(VII) = 27.92 cm^3 (1)

Moles manganate = 27.92 × 0.020 / 1000 = 5.584 × 10^{-4} mol (1)

Moles oxalate = 5.584 × 10^{-4} × 5/2 = 1.396 × 10^{-3} mol (1)

Concentration = 1.396 × 10^{-3} / 25 × 10^{-3} = 0.0558 mol dm^{-3} (1) [4]

(f) (i) $K_a = \frac{[H^+][HCOO^-]}{[HCOOH]}$ [1]

(ii) $[H^+]^2 = K_a \times [HCOOH] = 1.8 \times 10^{-4} \times 0.2 = 0.36 \times 10^{-4}$ (1)

$[H^+] = 6.0 \times 10^{-3}$ mol dm^{-3} (1)

pH = –log $[H^+]$ = 2.22 (1) [3]

(iii) A buffer keeps the pH almost constant when **small amounts** of acid or base are added (1)

$HCOOH \rightleftharpoons HCOO^- + H^+$ (1)

Adding acid shifts the equilibrium to the left which removes H^+ /
Adding base removes H^+ shifts equilibrium to right which replaces H^+ (1)
OR answer in terms of H^+ reacting with methanoate from
sodium methanoate when acid added (1) and methanoic acid replacing H^+
when base removes H^+ (1)

MAX 3 [3]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

(g) (i) Orange to green [1]

(ii) CrO_4^{2-} (1) Yellow (1) [2]

Total [20]

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5. (a) Lead(II) iodide or PbI_2 (1) Bright yellow (1) [2]

(b) $2Cu^{2+} + 4I^{-} \rightarrow 2CuI + I_2$ (1)

The precipitate is copper(I) iodide (stated or clearly indicated by state symbols) (1) [2]

(c) Bromine has a more positive E^{θ} than iodine so it is a stronger oxidising agent (1)

Bromine is able to oxidise iodide (1)

Bromine has a less positive E^{θ} than chlorine so it is a weaker oxidising agent (1)

Bromine is not able to oxidise chloride (1)

MAX 3

OR Calculate EMF for each reaction (1 each) and state that positive EMF means reaction is feasible (1) [3]

QWC Legibility of text, accuracy of spelling, punctuation and grammar, clarity of meaning [1]

(d) 1 mark for each two products or observations
$KHSO_4$ HI H_2S SO_2 S I_2 [MAX 2 for products]

Yellow solid rotten egg smell steamy fumes

Black solid or brown solution or purple fumes

MAX 3 [3]

(e) (i) Measure time taken for a sudden colour change (1)
Rate = 1 ÷ time (1) [2]

(ii) I. pH 1 has a concentration of H^+ ten times higher than pH 2. [1]

II. Order with respect to H_2O_2 = 1 (1)
Order with respect to I^- = 1 (1)
Order with respect to H^+ = 0 (1) [MAX 2 for the stated orders]
Rate = $k[H_2O_2]\,[I^-]$ (1) [3]

III. k = 0.028 (1) $mol^{-1}dm^3\,s^{-1}$ (1) [ecf from rate equation] [2]

IV. Rate equation is unchanged and increasing temperature increases the value of the rate constant [1]

Total [20]

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