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General Certificate of Education

Chemistry 2421

CHEM5 Energetics, Redox and Inorganic Chemistry

Mark Scheme

2010 examination - January series

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

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Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)		Alternative route Lower activation energy	1 1	Allow mechanism outlined allow forms intermediate species
1	(b)		Variable oxidation state	1	allow changes oxidation states
1	(c)	(i)	$SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$ $O_2 + 2V_2O_4 \rightarrow 2V_2O_5$	1 1	allow $2VO_2$ instead of V_2O_4
1	(c)	(ii)	Poison attaches to surface	1	Allow blocks active site/surface Decreases surface area
1	(c)	(iii)	Purify reactants	1	Allow remove impurities

Question	Part	Sub Part	Marking Guidance	Mark	Comments
2	(a)		1.4 V	1	Allow + or -
2	(b)		$2NiO(OH) + 2H_2O + Cd \rightarrow 2Ni(OH)_2 + Cd(OH)_2$ Balanced	1 1	Mark for species, Deduct a mark for additional species (eg OH^-) but allow balance mark If equation is reversed CE=0
2	(c)		NiO(OH) or Ni(III) or nickel +3	1 1	 Allow conseq on wrong species

Question	Part	Sub Part	Marking Guidance	Mark	Comments
3	(a)		By definition	1	allow 'set to this value'
3	(b)		1.23 V	1	Allow + or -
3	(c)		$Pt\|H_2(g)\|OH^-(aq),H_2O(l)\|\|O_2(g)\|H_2O(l),OH^-(aq)\|Pt$ Correct but with Pt missing Includes Pt with correct representation	 1 1	H_2O not essential, allow reverse order
3	(d)		Uses $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ And (2x) $2OH^- + H_2 \rightarrow 2H_2O + 2e^-$ $2H_2 + O_2 \rightarrow 2H_2O$	1 1	
3	(e)		Increases the surface area (so reaction faster)	1	
3	(f)		Overall reaction is the same ($2H_2 + O_2 \rightarrow 2H_2O$)	1	Or shows e.m.f. is the same
3	(g)		Hydrogen and oxygen supplied continuously ***OR*** Can be operated without stopping to recharge	1	Or can be refuelled quickly Allow any one mark
3	(h)		Hydrogen may need to be made using an energy source that is not 'carbon neutral'	1	

Question	Part	Sub Part	Marking Guidance	Mark	Comments
4	(a)		242	1	Units not essential
4	(b)		Bond is shorter or bonding pair closer to nucleus So attraction (between nucleus and) (to) bond pair is stronger	1 1	Allow Cl is a smaller atom Allow fewer electron shells do not allow smaller molecules Allow shared pair (or bonding electrons) held more tightly Mention of Cl^- loses M2
4	(c)		Net attraction between the chlorine nucleus and the extra electron	1	Allow Cl^- ion more stable than Cl
4	(d)	(i)	step 1 $Ag(s) \rightarrow Ag(g)$ only change step 2 $Ag(s) \rightarrow Ag^+(g) + e^-$ only change step 3 $^1/_2Cl_2(g) \rightarrow Cl(g)$ only change	1 1 1	 This step can be first, second or third
4	(d)	(ii)	127 + 289 + 732 + 121 – 364 = 905 kJ mol^{-1}	1 1	 -905 scores 1 mark only
4	(e)	(i)	Ions can be regarded as point charges (or perfect spheres)	1	Allow no polarisation ***OR*** only bonding is ionic ***OR*** no covalent character
4	(e)	(ii)	Greater Chloride <u>ions</u> are smaller than bromide They are attracted more strongly to the silver ions	1 1 1	Electronegativity argument or mention of intermolecular, CE =0 Mark independently but see above Mark independently
4	(e)	(iii)	AgCl has covalent character Forces in the lattice are stronger than pure ionic attractions	1 1	Ignore reference to molecules Allow stronger bonding OR additional/extra bonding

Question	Part	Sub Part	Marking Guidance	Mark	Comments
5	(a)		No disorder (or maximum order or molecules stationary)	1	Allow by definition Do not allow just 'particles are ordered'
5	(b)		Molecules <u>vibrate</u> more (so more disorder)	1	
5	(c)		Melting point of ammonia	1	
5	(d)		Molecules changing from liquid to gas <u>Big</u> increase in disorder or <u>much more</u> random movement	1 1	Allow becomes a gas Allow gases are <u>very</u> disordered
5	(e)	(i)	= Σentropy products – Σentropy reactants Or = 193 – 0.5×192 – 1.5×131 = –99.5 J K^{-1} mol^{-1}	 1 1	
5	(e)	(ii)	$\Delta G = \Delta H - T\Delta S$ When $\Delta G = 0$ $T = \Delta H/\Delta S$ = –46.2×1000/–99.5 = 464 K	1 1 1 1	 Allow conseq on wrong ΔS Allow 568 K if use given ΔS
5	(e)	(iii)	No longer spontaneous or yield decreases	1	Either point scores do not allow 'formation of ammonia decreases' Must say or imply clearly that yield of ammonia decreases or equilibrium shifts to left.

Question	Part	Sub Part	Marking Guidance	Mark	Comments
6	(a)		$Pt(NH_3)_2Cl_2 + H_2O \rightarrow [Pt(NH_3)_2Cl(H_2O)]^+ + Cl^-$ Correct product Balanced equation	 1 1	
6	(b)	(i)	Hydrogen bond Oxygen (or nitrogen)	1 1	 Only score this mark if type of bond is correct
6	(b)	(ii)	Co-ordinate Nitrogen (or oxygen)	1 1	 Bond type must be correct to score this mark but allow M2 if bond is covalent
6	(c)		Killing them or causing damage (medical side effects) May attach to DNA in normal cells	1 1	Allow any correct side effect (e.g. hair loss) Allow kills healthy (or normal) cells

Question	Part	Sub Part	Marking Guidance	Mark	Comments
7	(a)		$[Co(H_2O)_6]^{2+}$	1	
			octahedral	1	Only allow if species has 6 ligands but allow if M1 not given because charge missing
7	(b)		$CoCO_3$	1	Mark independently
			Purple solid (allow pink)	1	Allow pink precipitate
7	(c)		$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$		Allow $[Co(NH_3)_5H_2O]^{3+}$
			Formula of product	1	
			Balanced equation	1	
7	(d)		$[Co(NH_3)_6]^{3+}$	1	Allow $[Co(NH_3)_5H_2O]^{3+}$
			Oxidising agent	1	
7	(e)		$[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$	1	Allow use of en $[Coen_3]^{2+}$
			Entropy change for reaction is positive	1	Mark independently
			Because 4 mol reactants form 7 mol products (or increase in number of particles)	1	Or bidentate replaces unidentate
7	(f)		$[CoCl_4]^{2-}$	1	
			Cl^- ligand too big to fit more than 4 round Co^{2+}	1	Allow Cl^- is bigger Allow chlorine and Cl but NOT chlorine molecules.

Question	Part	Sub Part	Marking Guidance	Mark	Comments
8	(a)		Electronegativity increases	1	
			Proton number increases (increase in nuclear charge)	1	
			Same number of electron shells/levels	1	Or same radius or Shielding of outer electrons remains the same
			Attraction of <u>bond pair</u> to nucleus increases	1	Allow 'electrons in bond' instead of 'bond pair'
8	(b)		Big <u>difference</u> in electronegativity leads to ionic bonding, smaller covalent	1	Lose a mark if formula incorrect
			Sodium oxide ionic lattice	1	
			Strong forces of attraction <u>between ions</u>	1	
			P_4O_{10} covalent molecular	1	Must have covalent and molecular (or molecules)
			Weak (intermolecular) forces between molecules	1	Or weak vdW, or weak dipole-dipole between molecules
			melting point Na_2O greater than for P_4O_{10}	1	Or argument relating mpt to strength of forces

8	(c)		Moles NaOH = $0.0212 \times 0.5 = 0.0106$ Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353) Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$ Moles of $P_4O_{10} = 3.53 \times 10^3/4$ Mass of $P_4O_{10} = 3.53 \times 10^3/4 \times 284 = 0.251 \times 10^6$ g = 251 kg	1 1 1 1 1	M1 moles of NaOH correct M2 is for 1/3 M3 is for factor of 1,000,000 M4 is for factor of 1/4 (or 1/2 if P_2O_5) (Or if P_2O_5 $3.53 \times 10^3/2 \times 142$) M5 is for multiplying moles by M_r with correct units allow conseq on incorrect M4 (allow 250-252)

Question	Part	Sub Part	Marking Guidance	Mark	Comments
9	(a)		Ti(IV) [Ar]	1	Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
			Ti(III) [Ar]$3d^1$	1	Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$
			Ti(III) has a d electron that can be excited to a higher level	1	Allow idea that d electrons can be excited to another level (or move between levels)
			Absorbs one colour of light from white light	1	Allow idea that light is absorbed
			Ti(IV) has no d electron so no electron transition with energy equal to that of visible light	1	Allow Ti(IV) has no d electrons
9	(b)		$[Cu(NH_3)_4(H_2O)_2]^{2+}$	1	
			$[Cr(OH)_6]^{3-}$	1	
			$[CuCl_4]^{2-}$	1	
9	(c)	(i)	Rapid determination of concentration	1	Or easy to get many readings
			Does not use up any of the reagent/does not interfere with the reaction	1	Or possible to measure very low concentrations
9	(c)	(ii)	Curve starts with small gradient (low rate)	1	**5 max**
			Because negative ions collide so E_a high	1	
			Curve gets steeper	1	
			Because autocatalyst (Mn^{2+}) formed	1	
			Curve levels out approaching time axis	1	Can score this mark and next one ONLY with simple curve (that is curve with gradually decreasing gradient)
			Because MnO_4^- ions used up	1	