Oxidation and Reduction (HL)

Markscheme Notes:

1. A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover sheet.

12. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, do not award a mark for a correct name.

13. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.

14. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

Answers:

1. A

[1]

2. B

[1]

3. *Dilute sodium chloride:*
$2H_2O \rightarrow O_2 + 4H^+ + 4e^- / 4OH^- \rightarrow O_2 + 2H_2O + 4e^-$;

Concentrated sodium chloride:
$2Cl^- \rightarrow Cl_2 + 2e^-$; 2

Accept alternative balanced half-equations with correct number of electrons.
*Award **[1 max]** if equations are given the wrong way round.*
*Award **[2]** if correct equations are written in order with dilute sodium chloride first and concentrated sodium chloride second but processes not stated explicitly.*
Penalize once only.
Allow e instead of e^-.
Ignore state symbols.

[2]

4. (i) $Sn + Cu^{2+} \rightarrow Sn^{2+} + Cu$; 1
Ignore state symbols.
Penalize once only.

(ii) (0.34 – –0.14) = (+) 0.48 V; 1

(iii) 1.0 mol dm^{-3} solutions **and** 25 °C/298 K; 1

[3]

5. Cd^{2+} is a stronger oxidizing agent than H_2O **and** will be displaced to produce Cd / *OWTTE*;
Cr^{2+} is a weaker oxidizing agent than H_2O **and** H_2 will displace in preference to Cr / *OWTTE*; 2
*Award **[1 max]** for stating Cd^{2+} stronger oxidizing agent than H_2O **and** Cr^{2+} weaker oxidizing agent than H_2O / OWTTE.*

[2]

6. (i) Ni;
only requires 2 mol of e^- for each mol of Ni / Sn requires 4 mol of e^- / Cr requires 3 mol of e^- / Ni^{2+} needs least number of e^- to produce 1 mol of Ni metal;
Allow e instead of e^-.

cathode / negative electrode; 3
Do not award M3 for "metal deposited at cathode where oxidation occurs".

(ii) temperature of solution;
$[Sn^{4+}]$;
surface area/size of electrode;
material of electrodes; 2 max
Do not allow nature of electrodes.

[5]

7. D

[1]

8. B

[1]

9. (i) the potential difference/voltage obtained when a half-cell is connected to a standard hydrogen electrode;
under standard conditions / 1.00 mol dm^{-3} solutions, 298 K; 2

(ii) the electrons flow from the half-cell to the standard hydrogen electrode / the half-cell forms the negative electrode when connected to the standard half-cell / Fe is a better reducing agent than H_2 / Fe is above H_2 in electrochemical series; 1
Accept "the half reaction is not spontaneous".

[3]

10. (i) bromine/Br_2; 1

(ii) hydrogen/H_2; 1

(iii) iron/Fe; 1

Ignore coefficients for Br_2, H_2 or Fe.

[3]

11. (i) sodium is a very powerful reducing agent/high in electrochemical series;
any chemical reducing agent would need to be even higher in ECS to reduce Na^+ / *OWTTE*; 2 max

(ii) H^+ ions gain electrons more readily than Na^+ / hydrogen is evolved instead;
hydrogen is below Na in ECS;
if sodium were to be formed it would react with the water in the solution / *OWTTE*; 2 max

[4]

12. D

[1]

13. C

[1]

14. (a) (i)

correctly labelled electrodes and solutions;
labelled salt bridge;
voltmeter;
Allow bulb or ammeter.

direction of electron flow; 4

(ii) *Oxidation:*
$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^{-}$;

Reduction:
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$;

Ignore state symbols.
*Award **[1 max]** if equations not labelled reduction or oxidation or labelled the wrong way round.*
Allow e instead of e^{-}.
Penalize equilibrium sign or reversible arrows once only. 2

(iii) +0.80 – (–2.37) = 3.17 V
correct data;
answer with unit;
*Award **[1]** for –3.17 V or correct working of wrong values.* 2

(b) (i) Cd/Cd(s);
Do not allow Cd^{2+}. 1

(ii) $5Cd(s) + 2MnO_4^{-}(aq) + 16H^{+}(aq) \rightarrow 5Cd^{2+}(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$
correct reactants and products;
correct balancing of this equation;
Ignore state symbols. 2

(c) *Accept suitable diagram with the following indicated:*
Pt electrode;
$[H^{+}(aq)] = 1$ mol dm^{-3}/0.5 mol dm^{-3} H_2SO_4;

H_2 gas;
at 1 atm / 1.01×10^5 Pa;
Do not award mark for pressure if no hydrogen gas given.

298 K / 25 °C; 4 max

[15]

15. (i) sodium chloride crystals consist of ions in a (rigid) lattice / ions cannot move (to electrodes) / *OWTTE*;
when melted ions free to move / ions move when potential difference/voltage applied; 2

(ii) positive sodium ions/Na^+ move to the negative electrode/cathode **and** negative chloride ions/Cl^- move to the positive electrode/anode;
electrons are released to positive electrode/anode by negative ions and accepted from negative electrode/cathode by positive ions / reduction occurs at the negative electrode/cathode **and** oxidation occurs at the positive electrode/anode / Na^+ ions are reduced **and** Cl^- ions are oxidized;

(Positive electrode/anode):
$2Cl^- \rightarrow Cl_2 + 2e^-$ / $Cl^- \rightarrow Cl_2 + e^-$;

(Negative electrode/cathode)
$2Na^+ + 2e^- \rightarrow 2Na$ / $Na^+ + e^- \rightarrow Na$;

*Award **[1 max]** if equations not labelled or labelled wrong way round.*
Allow e instead of e^-.
Penalize equilibrium sign or reversible arrows once only. 4

(iii) *Products:*
oxygen at positive electrode **and** hydrogen at negative electrode;
moles of Mg = 0.5 / mole ratio of O_2:H_2 is 1:2;
Can be implied by calculation.

mass oxygen = 8.00 g;
mass hydrogen = 1.01 g;
Do not apply SD rule here. 4

[10]

16. D

[1]

17. (i) Positive/+/anode
$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$;
Allow e instead of e^-.

Negative/–/cathode
$Na^+(l) + e^- \rightarrow Na(l)$;
Penalize missing or incorrect states such as (aq) or (s) once only.
*Award only **[1]** if electrodes not specified or if equations switched.*

$1Cl_2$ to 2Na; 3

(ii) (choice of Cl^- or H_2O/OH^- to be oxidized), Cl^- oxidized because of concentrated solution/higher concentration / *OWTTE*;
(choice of Na^+ or H_2O/H^+ to be reduced), H_2O/H^+ reduced because Na^+ is a (much) weaker oxidizing agent / Na^+ not reduced to Na in water / H^+ easier to reduce than Na^+ / *OWTTE*;

positive/+/anode
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$;

negative/–/cathode
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ / $2H^+(aq) + 2e^- \rightarrow H_2(g)$;
Penalize missing or incorrect states once only.
*Award only **[1]** out of the last two marks if electrodes not specified or if equations switched.*
Allow e instead of e^-. 4

[7]

18. *Positive/+/anode*
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ /$H_2O(l) \rightarrow O_2(g) + 2H^+(aq) + 2e^-$ /
$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$;

Negative/–/cathode
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$;
Ignore state symbols.
*Award only **[1]** if electrodes not specified or if equations switched.*
Allow e instead of e^-.

*Observations: **[2 max]***
blue colour of $Cu^{2+}(aq)$ ⊠ fades;
Cu/metal deposited on negative/–/cathode/tin (jewelry);
gas produced/bubbles formed (at positive/+/anode);
pH of solution decreases/acidity increases (observed with indicator/pH paper); 4 max

[4]

19. B

[1]

20. A

[1]

21. C

[1]

22. (i) contains ions which are free to move (only) in molten state;
Mg^{2+} move to cathode/negative electrode and Cl^- move to anode/positive electrode / *OWTTE*; 2

(ii) anode/positive electrode;
$2Cl^- \rightarrow Cl_2 + 2e^-$ / $Cl^- \rightarrow Cl_2 + e^-$;
Accept e instead of e^-.
Do not accept $Cl^- \rightarrow Cl + e^-$.
Ignore state symbols. 2

(iii) magnesium has large negative electrode potential / $E^{\ominus}$;
reduction of H_2O/H^+ to H_2 has less negative electrode potential;
Mg^{2+} not readily reduced (in comparison to H_2O);
if formed, magnesium would (immediately) react with water to form Mg^{2+};
magnesium more reactive than hydrogen;
Do not accept Mg too reactive. 1 max

[5]

23. B

[1]

24. B

[1]

25. (i) the voltage obtained when the half-cell is connected to the standard hydrogen electrode;
under standard conditions of 298 K **and** 1 mol dm^{-3} solutions;
electrons flow (in the external circuit) from the half-cell to the hydrogen electrode / the metal in the half-cell is above hydrogen in the ECS / Fe is a better reducing agent than H_2 / Fe is oxidized more readily than H_2; 3

(ii) –0.28 V; 1

(iii) Co^{2+}/cobalt(II) ion; 1

(iv) $2Al + 3Fe^{2+} \rightarrow 3Fe + 2Al^{3+}$;
*Award **[1]** for correct reactants and products and **[1]** for correctly balanced, ignore states.*
Do not accept 2

(v) to complete the electrical circuit / *OWTTE*;
by allowing the movement of ions; 2

[9]

26. (a) (i) diagram to show:

battery/source of electricity connected to two electrodes in the solution with positive and negative electrodes correctly labelled;
electrons/current flowing from the cell to the negative electrode;
labelled solution of sodium chloride;
*If the connecting wires to electrodes are immersed in the solution **[1 max]**.* 3

(ii) Na^+, H^+/H_3O^+, Cl^-, OH^-
*All four correct **[2]**, any three correct **[1]**.* 2 max

(iii) hydrogen at (–)/cathode **and** oxygen at (+)/anode;
$2H^+ + 2e^- \rightarrow H_2$ / $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$;
$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ / $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$;
Accept e instead of e^-
*If electrodes omitted or wrong way round **[2 max]**.* 3

(iv) Ratio of H_2:O_2 is 2:1; 1

(b) (i) (–)/(cathode)$2H^+ + 2e^- \rightarrow H_2$ / $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$;
(+)/(anode) $2Cl^- \rightarrow Cl_2 + 2e^-$;
Accept e instead of e^-.
*If electrodes omitted or wrong way round **[1 max]*** 2

(ii) (–)/(cathode) $Na^+ + e^- \rightarrow Na$;
(+)/(anode) $2Br^- \rightarrow Br_2 + 2e^-$;
Accept e instead of e^-.
*If electrodes omitted or wrong way round **[1 max]**.* 2

[13]

27. C

[1]

28. A

[1]

29. B

[1]

30. (i) $2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$;
*Correct reactants and products, award **[1]***
*Balancing award **[1]**.*
Ignore state symbols and equilibrium sign. 2

(ii) (+) 1.40 (V) ✗✗; 1

(iii) aluminium anode/negative electrode;
nickel cathode/positive electrode;
electron movement from Al to Ni;
correct movement of cations and anions through salt bridge;
If electron movement shown correctly but not labelled, award the mark
4

[7]

31. C

[1]

32. A

[1]

33. (a) Pt electrode;
1 mol dm^{-3} $[H^+(aq)]$;
H_2 gas;
at 1 atm/1.01×10^5 Pa;
298 K/25°C; 5

Accept suitable labelled diagram with the above.

(b) electron acceptor;
F_2/fluorine; 2

(c) (i) (+)0.48 (V); 1

(ii) $Cu^{2+}(aq) + Sn(s) \rightarrow Sn^{2+}(aq) + Cu(s)$ 2

*Award **[1]** for correct reactants and products from (c)(i), and **[1]** for state symbols.*

[10]