Answers

1. B

[1]

2. D

[1]

3. C

[1]

4. D

[1]

5. B

[1]

6. A

[1]

7. D

[1]

8. C

[1]

9. A

[1]

10. C

[1]

11. C

[1]

12. D

[1]

13. D

[1]

14. B

[1]

15. B

[1]

16. A

[1]

17. C

[1]

18. D

[1]

19. A

[1]

20. D

[1]

21. C

[1]

22. C

[1]

23. A

[1]

24. (a) (i) ionic conductor/allows movement of ions between electrolytes /completes circuit; 1

(ii) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ *(state symbols not needed)*; 1

(iii) 298 K/25°C, 1 atm/1.01×10^5Pa, 1 mol dm^{-3} solutions; 2
*(all 3 for **[2]**, 2 for **[1])***

(iv) 0.34 – (–0.76) = 1.10 V; 2
***[1]** for finding correct data, **[1]** for answer with unit (ECF).*

(v) decreases;
Cu^{2+} ions are converted to Cu metal/Cu deposited on electrode; 2
Allow ECF from (iv).

(vi) Cu deposited on Zn rod/rod goes pink/brown;
blue colour of solution → paler;
gets hotter/temperature increase/exothermic; 2 max

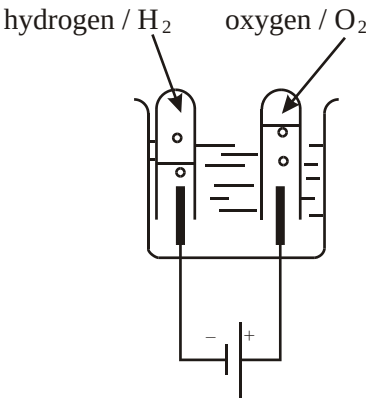
(b) (i) Ti^{2+} *(no ECF to explanation)*;
Ti^{2+} has greatest tendency to lose electrons/Ti^{3+} has least tendency to gain electrons; 2

(ii) $Ce^{4+}(aq) + Ti^{2+}(aq) \rightarrow Ce^{3+}(aq) + Ti^{3+}(aq)$ 2
***[1]** for equation, **[1]** for state symbols. If wrong equation is given, award **[1]** for state symbols.*

(iii) $\Delta G^{\ominus}$ negative;
reaction spontaneous/corresponds to positive cell potential; 2
*Positive **[0]**, non-spontaneous **[1]**.*

(c) (i) (aqueous) sodium hydroxide/dilute sulfuric acid/sodium sulfate; 1
Accept correct formulas.
Any combination of $K^+/Na^+/H^+$ and NO_3^-/SO_4^{2-}.
*Halides **not** acceptable. ("water" is not a solution)*

(ii)



Or similar suitable diagram.
gas collection method;
names of gases correct way round at electrodes;
2:1 volume ratio correct way round; 3

[20]

25. (i) mass increases;
copper deposited;
because X is negative and attracts Cu^{2+} ions/reduction occurs at X/
$Cu^{2+} + 2e^- \rightarrow Cu$; 3

(ii) increase time;
increase current; 2

[5]

26. (a) (i) ($[H^+]$=)1 mol dm^{-3};
298 K/25°C;
1 atm/101.3 or 101 kPa 3
Accept 100 kPa;

(ii) $E^{\ominus}$(=0.76 +0.34) = (+)1.1(0)(V);
from zinc/Zn to copper/Cu;
copper/Cu deposited/electrode becomes larger/thicker/heavier;
zinc/Zn electrode becomes smaller/thinner/lighter;
Cu^{2+} solution becomes paler/colourless; 5
Allow ECF for –1.1 V, all answers must be consistent with the error.

(b) no (spontaneous) reaction;
appropriate use of Table 15/$E^{\ominus}$ = –0.34 + 0.00 = –0.34 V/$E^{\ominus}$ value for the reaction would be negative; 2

(c) $O_2/Cr_2O_7^{2-}$;
Accept names.

$E^{\ominus}$ value for the reaction with Br^- is positive/suitable calculation to show this;
$E^{\ominus}$ value for the reaction with Cl^- is negative/Cl_2 stronger oxidizing agent than $O_2/Cr_2O_7^{2-}$; 5

$4Br^- + O_2 + 4H^+ \rightarrow 2Br_2 + 2H_2O/Cr_2O_7^{2-} + 14H + 6Br^- \rightarrow 2Cr^{3+} + 7H_2O + 3Br_2$;

*Award **[1]** for all formulas correct, **[1]** if coefficients correct.*

[15]

27. (a) 0.2 mol;
the $Na:Cl_2$ mol ratio is 2 : 1; 2

(b) $0.1 \times \frac{1}{2} \times 5$;

= 0.25 mol; 2

(c) *negative electrode*
hydrogen/H_2;

$2H^+ + 2e^- \rightarrow H_2/2H_2O + 2e^- \rightarrow H_2 + 2OH^-$;

positive electrode
oxygen/O_2;

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-/2H_2O \rightarrow O_2 + 4H^+ + 4e^-$. 4

[8]

28. the potential/voltage difference between the element and its ions;

(and) a hydrogen electrode;
under standard conditions/ion concentration at 1 mol dm^{-3}/298 K/25°C;
(+)1.23 (V);
$E^{\ominus}$ value more positive or less negative than bromine/bromide system/
$E^{\ominus}$ value of combined half-cells is positive/*OWTTE*;

$2Br^- + \frac{1}{2} O_2 + 2H^+ \rightarrow Br_2 + H_2O$;

*Award **[1]** for all formulas correct, **[1]** for correct balancing.*
*Award **[1]** for correct equation reversed.*

$E^{\ominus}$ (= 1.23 – 1.09) = (+)0.14 (V); 8

Ignore state symbols.

[8]

29. (i) (metal ions at) 1 mol dm^{-3} concentration;
25°C/298 K; 2

Do not accept 1 atm pressure.

(ii) $Ni^{2+} + 2e^- \rightarrow Ni$;
$Pb \rightarrow Pb^{2+} + 2e^-$; 2

No penalty for using e instead of e^-.
No penalty for $\rightleftharpoons$ *instead of* $\rightarrow$.

(iii) 0.15 V;
$10Cl^- + 2MnO_4^- + 16H + \rightarrow 5Cl_2 + 2Mn^{2+} + 8H_2O$; 3

Ignore state symbols.
*Correct reactants and products = **[1]***
*Correct balancing = **[1]***

(iv) not sufficiently good oxidizing agent/cell potential would have negative $E^{\ominus}$ value; 1

[8]

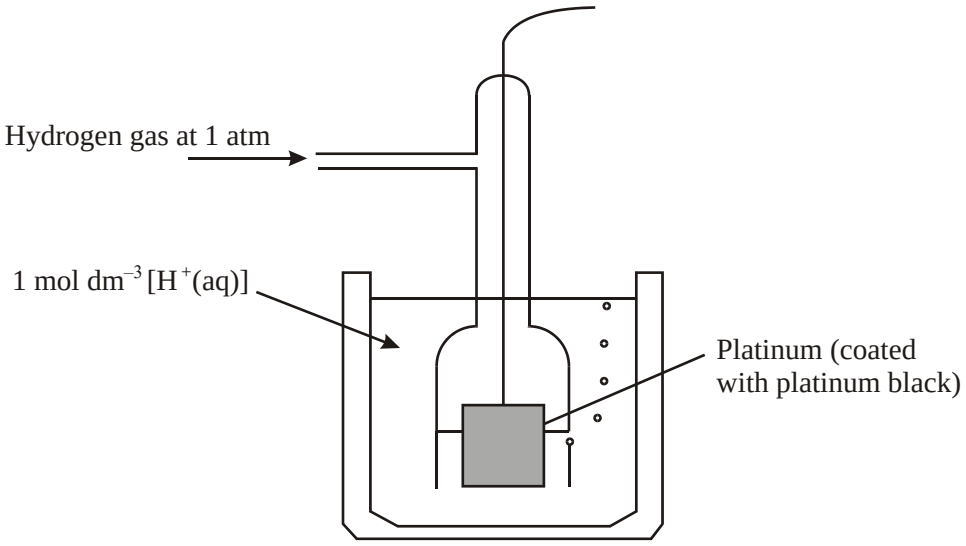
30. (a) (i) oxidation half-reaction: $2Cl^- \rightarrow Cl_2 + 2e^-$;
reduction half-reaction: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-/2H^+ + 2e^- \rightarrow H_2$ 2
*Award **[1]** only if equations are interchanged.*
States not required.

(ii) Na has high $E^{\ominus}_{red}$ / Na^+ not readily reduced (in comparison to H_2O)/if formed, Na would (immediately) react with water to form Na^+ 1

(b) H(g) and O_2(g)/*accept names*;
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-/4OH^- \rightarrow 2H_2O + O_2 + 4e^-$;
water is oxidized (instead of the halide);
since $E^{\ominus}_{OX}$ for F^- is very negative/$E^{\ominus}_{red}$ for F_2 is very high; 4
Accept answer based on oxidizing/reducing strengths.

[7}

31. (a)



Accept suitable diagram with the following indicated:

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

(b) electron acceptor;
Fe^{3+}(aq)/iron(III) ions/Fe^{3+}; 2

Do not accept iron/Fe^{2+}/iron ion.

(c) (i) (+)1.10; 1

(ii) $Cu^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cu(s)$; 2
*Award **[1]** for correct reactants and products from (c)(i), and **[1]** for state symbols.*

(d) (i) zinc;
zinc is more readily oxidised than iron and so protects it by reacting preferentially/*OWTTE* **or** tin is less readily oxidised than iron and so iron reacts preferentially/*OWTTE*; 2

(ii) charge on the ion discharged;
size/magnitude of the current;
time/duration of the electrolysis; 3

(iii) positive ions/cations in solution = $H^+(aq)$, $Zn^{2+}(aq)$;
$H^+(aq)$ discharged preferentially;

(e) (i) salt bridge;
allows movement of ions between the solutions/to complete the circuit/to maintain electrical neutrality; 2

(ii) A: $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$;
B: $Cr(s) \rightarrow Cr^{3+}(aq) + 3e^-$;
*Allow **[2]** for correct equation for the cell reaction if equations for A and B are reversed.*

$3\ Fe^{3+}(aq) + Cr(s) \rightarrow 3\ Fe^{2+}(aq) + Cr^{3+}(aq)$; 4
*Award **[1]** for correct reactants and products, with state symbols, and **[1]** for correct balancing.*

(iii) from B to A/from Cr to Pt/from right to left; 1
Allow ECF from (ii).

(iv) (+)1.51; 1
Allow ECF from (ii).

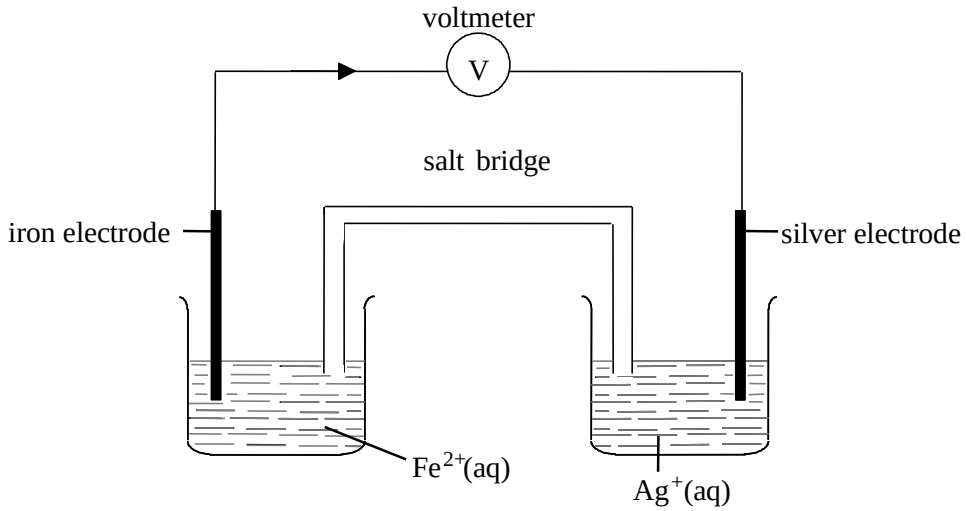
[25]

32. (a) $Fe + 2Ag^+ \rightarrow Fe^{2+} + 2Ag$; 1
Ignore state symbols.
Accept $Fe + 3Ag^+ \rightarrow Fe^{3+} + 3Ag$

(b) the potential difference/EMF/Voltage between a standard half-cell and standard hydrogen electrode/*OWTTE*; 1

(c) (+) 1.24 (V); 1
ECF from (a).

(d) electron flow indicated on wires; 1
ECF from (a).



[4]

33. (a) (i) I– = –1/1– **and** IO_3^- = +5/5+; 1

*Both answers needed for **[1]** mark,*
Signs must be included
Do not accept Roman numerals

(ii) *oxidation*

I^- (to I_2), increase in oxidation number/loss of electron(s);

reduction

IO_3^- (to I_2), decrease in oxidation number/gain of electron(s); 2

(iii) $5I^-(aq) + IO_3^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$; 2

*Award **[2]** if correctly balanced*
*Award **[1]** for correct reactants and products.*
States not required for mark.
***[1 max]** if HCl on left and Cl^- on right side*

(b) $Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$: $E^\ominus$ = (+) 0.15(V), $Cu(s) \rightleftharpoons Cu^+(aq) + e^-$:
$E^\ominus$ = – 0.52(V)/(+) 0.15 and – 0.52(V);

No mark if 0.34 or 0.52 quoted, but then ECF

($Cu^{2+}(aq) + Cu(aq) \rightleftharpoons 2\ Cu^+(aq)$) $E^\ominus$ value for reaction = – 0.37(V);

*Award **[2]** for correct $E_{rxn}^\ominus$ even if equations are not given, states not required.*

(negative value means) not spontaneous; 3

Allow ECF: if positive value, can score third mark for 'spontaneous'.

[8]

34. (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]