AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.7 OXIDATION, REDUCTION AND REDOX EQUATIONS

SCORE	PERCENTAGE
/235	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a) Two correct Cl ox states: HClO = +1 HCl = -1

1

(b) Oxidation:
$Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$

Accept - $2e^-$ on the other side

Allow $Cl_2 + 2H_2O \rightarrow 2ClO^- + 2e^-$

1

Reduction:
$Cl_2 + 2H^+ + 2e^- \rightarrow 2HCl$

Allow $Cl_2 + 2e^- \rightarrow 2Cl^-$

If both equations correct but incorrect order, allow 1

Ignore state symbols

1

(c) $2NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$

Allow

$2OH^- + Cl_2 \rightarrow Cl^- + ClO^- + H_2O$

Allow NaOCl

Ignore state symbols

1

(d) mol ClO^- = conc × vol = 0.0109 × 0.02
= <u>0.000218 / 2.18×10^{-4}</u> mol

1

mol KI = 0.000218 × 2 = 0.000436 mol

M2 = M1 x2

If incorrect ratio, M2 & M3 = 0

1

mass KI = Mr ×mol = 166.0 × 0.000436
= 0.072376 g
= 72.4 (mg)

M3 = M1 × 2 × 166.0 × 1000

Must be to <u>3 sig figs</u>

1

<u>black solid/ppt</u> appears/forms (in a colourless solution)
or (colourless solution) turns brown (solution)

Not purple. Not red. Not brown ppt/solid

Ignore grey.

1

(e) $KClO_4 \rightarrow KCl + 2O_2$

Ignore state symbols

Allow multiples

1

STEMUP.CO.UK

ΔH = – 436 – – 434 = – 2 kJ mol^{-1}

Must be negative
Mark independently
Allow consequential for multiples

1

[10]

Q2.

(a) (ΔS = Σ(*S products*) - Σ(*S reactants*))

= [(4 × 211) + (6 × 189)] - [(4 × 193) + (5 × 205)] = (1978 – 1797)

1

181 (J K^{-1} mol^{-1})

1

(b) ($\Delta G = \Delta H - T\Delta S$) = - 905 - (600 + 273) × 181 × 10^{-3}

If answer to (a) is incorrect, mark consequentially:
- 905 - (873 × (a) × 10^{-3})

1

ΔG = - 1063 / -1060 (kJ mol^{-1})

If alternative value of ΔS = 211 used, answer = -1089 (kJ mol^{-1})

1

(c) ΔG becomes more negative/less positive

Ignore increase/decrease/larger/smaller ΔG

1

The entropy change / ΔS is positive / $T\Delta S$ gets bigger / $-T\Delta S$ gets more negative.

Consequential on wrong (a)
If candidate does a calculation in (a) to produce ΔS negative then allow ΔG becomes less negative or more positive

1

(d) Reactant(s) adsorbed onto the (platinum surface) / (platinum) provides a surface / active sites

1

Reaction (on the surface) or bond breaking(weakening) / bond making occurs (on the surface)

1

Desorption (of the product) or wtte

1

(e) (Oxidation state changes from) -3 to +2 OR (+) 5

1

(f) $2NH_3 + 2O_2 \rightarrow N_2O + 3H_2O$

Allow multiples
Ignore state symbols

1

[11]

STEMUP.CO.UK

Q3.

(a) Fe^{2+}

Accept any Fe(II) compound – correct formula or name

1

$E^{\ominus}$ VO_2^+(/ VO^{2+}) > $E^{\ominus}$ Fe^{3+}(/Fe^{2+}) > $E^{\ominus}$ VO^{2+}(/V^{3+})

If calculations of EMF are provided producing EMFs = 0.23(V) and -0.43(V), with a comment, allow M2

allow $E^{\ominus}$ Fe^{3+} (/Fe^{2+}) value of +0.77 is between the $E^{\ominus}$ values for the electrode half-equations containing the V species or wtte

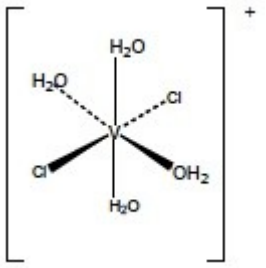
1

(b) (+) 4

IV or four

1

(c)



Ignore absence of charge

Wedges, dotted lines and [ ] not required

Do not penalise bond from H to V (in water ligands)

1

Cis/trans

allow E/Z, geometric and stereo(isomerism)

1

(d) $2\ NH_4VO_3 \rightarrow V_2O_5 + H_2O + 2NH_3$

Accept multiples

Ignore state symbols

1

(e) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

$V_2O_4 + ½\ O2 \rightarrow V_2O_5$

Both equations needed for 1 mark in this order

Allow multiples

1

[7]

Q4.

(a) NO_2^- +3 or III or 3 or 3+

1

NO +2 or II or 2 or 2+

1

(b) $NO_2^- + e^- + 2H^+ \rightarrow NO + H_2O$ (OR double)

STEMUP.CO.UK

1

(c) $2I^- \rightarrow I_2 + 2e^-$ (OR half)

1

(d) $2NO_{2-} + 2I^- + 4H^+ \rightarrow I_2 + 2NO + 2H_2O$

1

(e) Oxidising agent

Allow to accept / gain electrons

Allow Oxidant

Do not allow accept / gain pairs of electrons

Do not allow Oxidise

1

(f) Mol ClO_3^- = $0.02 \times \frac{27.4}{1000} = 5.48 \times 10^{-4}$

1

Mol NO_2^- = $\frac{5}{2}$ $(0.02 \times \frac{27.4}{1000}) = 1.37 \times 10^{-3}$)

1

$[NO_2^-]$ = mol NO_2^- /$(\frac{25}{1000})$

$[NaNO_2] = 0.0548$ moldm^{-3}

1

Conc $NaNO_2 = (0.0548) \times 69.0 = 3.78$ gdm^{-3}

1

Minimum 2 sf

[10]

Q5.

B

[1]

Q6.

A

[1]

Q7.

(a) (+) 5

1

(+) 2

1

Allow Roman numerals

(b) Cl^- / chloride (ions)

Allow $2Cl^-$

Do not allow chlorine / Cl / Cl_2

Ignore (aq)

1

STEMUP.CO.UK

(c) nitric acid / HNO_3

If not nitric acid then CE = 0

If NO_3^- ions identified, lose M1 and mark on

Allow 0.96V > 0.34V

1

the E^θ **NO_3^-** (/NO) > E^θ **Cu^{2+}**(/Cu) or in words

*Allow **NO_3^-** is a better oxidising agent than **Cu^{2+}***

*Allow **NO_3^-** has a more positive E^θ than **Cu^{2+}***

1

$3Cu + 8H^+ + 2NO_3^- \longrightarrow 3Cu^{2+} + 2NO + 4H_2O$

Allow $3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

1

EMF for the reaction is <u>0.62(V)</u>

1

[7]

Q8.

C

[1]

Q9.

B

[1]

Q10.

D

[1]

Q11.

(a) $[Kr]\ 5s^2\ 4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some

STEMUP.CO.UK

steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \longrightarrow HI$

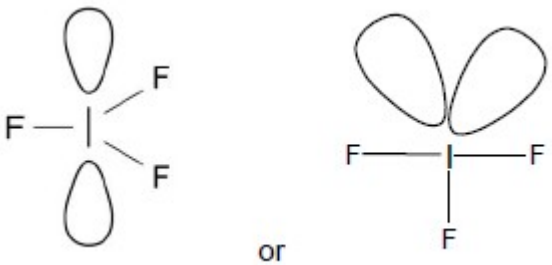
Allow multiples

1

(e) NH_4I_3

1

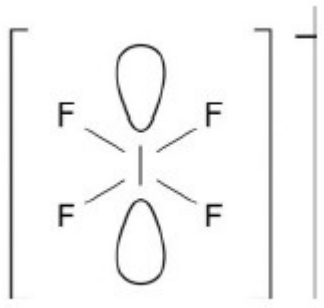
(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1

STEMUP.CO.UK



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q12.

D

[1]

Q13.

C

[1]

Q14.

B

[1]

Q15.

D

[1]

Q16.

D

[1]

Q17.

(a) $6S_2O_3^{2-} + BrO_3^- + 6H^+ \rightarrow 3S_4O_6^{2-} + Br^- + 3H_2O$

Check the formulae and charges carefully and penalise any transcription errors.

Allow multiples and fractions.

Ignore state symbols.

1

STEMUP.CO.UK

(b) Mol of thio = 25.0 × 0.00100 / 1000 = 2.50×10^{-5}

and
Mol of bromate(V) = (1/6) × 2.5 x 10^{-5} = 4.17×10^{-6}

If equation in Q5a is wrong, mark consequentially.

1

Vol of bromate(V) = (4.17×10^{-6} / 0.005) × 1000 = 0.83 cm^3

Lose this mark if (correct) unit of volume not given.

Do not penalise precision.

1

(c) Use a more dilute solution of sodium bromate

Allow 'use a bigger volume of sodium thiosulfate solution'.

1

[4]

Q18.

(a) Reheat the sample at least once.

Heat to constant mass gains both marks.

1

Mass of ash should not have changed.

Mark independently.

1

(b) Vacuum filtration is quicker / saves time

Allow 'easier to wash residue to extract all iodide ions'.

1

(c) Use indicator (paper) on a withdrawn sample / place a pH probe into the solution

If any indicator (including paper) is used directly on the solution lose this mark but then mark on.

1

Keep testing until paper shows acidity / until pH drops below 7.

Indicator does not need to be specified but if it is then correct colour must be quoted.

1

(d) $2I^- + H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$

Do not accept $2I^- + H_2O_2 \rightarrow I_2 + 2OH^-$ as reaction conditions are acidic.

Accept multiples and fractions.

Ignore state symbols.

1

(e) Lower layer – as it will be the denser CCl_4

Mark is for correct identification and correct reasoning.

1

(f) Iodine in seaweed = 56.4 × (3/100) = 1.692 g

1

Iodine left in aqueous layer = 1.692 – 1.673 = 0.0190 g

STEMUP.CO.UK

1

K = (1.673/(253.8 × 0.05)) / (0.0190/(253.8 × 0.05)) = 88.1

Neither 253.8 nor 0.05 have to appear in working since they cancel.

Accept 88

1

(g) It would react with the iodine

*Allow (electrophilic) addition **OR** forms 1,2 – diiodocyclohexane **OR** addition across a double bond for **both** marks.*

1

It is unsaturated

1

(h) Solubility (of the iodine in the solvent) is high when hot and low when cold

1

(Therefore, on cooling a solution,) a significant quantity of crystals appear

1

[14]

Q19.

(a) $2Cl^- \longrightarrow Cl_2 + 2e^{(-)}$

Allow $2Cl^- - 2e^{(-)} \longrightarrow Cl_2$

Allow correct equation forming ClO^- but not Cl^+

1

(b) $2ClO^- + 4H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$

Allow HClO in correctly balanced equation

1

(c) $ClO^- + Cl^- + 2H^+ \longrightarrow Cl_2 + H_2O$

allow $HClO + HCl + \longrightarrow Cl_2 + H_2O$

1

(d) Goes brown (or shades of brown)

Allow black ppt/solid but NOT black solution or purple

1

Due to iodine or I_3^-

Correct ½ equation scores M2 and M3

1

Because I^- oxidised

1

[6]

Q20.

C

[1]

STEMUP.CO.UK

Q21.

C

[1]

Q22.

B

[1]

Q23.

(a) Increasing atomic radius / shielding / number of shells / size (down group) or reverse argument

NOT *'molecules'*

1

Decreasing attraction of nucleus/protons for shared (electron) pair / bond electrons

NOT *if attraction for single electron implied*

1

(b) (i) Electron acceptor / species that accepts electrons / species that gains electrons

NOT *electron pair*

NOT *just 'gain of electrons'*

1

(ii) Chlorine 0 to –1 / oxidation state/number of chlorine decreases
AND
Bromine –1 to 0 / oxidation state/number of bromine increases

Penalise if oxidised for chlorine and/or reduced for bromine

Credit oxidation states if labelled on equation

1

(c) (i) $H_2SO_4 + 8H^+ + 8e^{(-)} \longrightarrow H_2S + 4H_2O$

ALLOW $SO_4^{2-} + 10H^+ + 8e^{(-)} \longrightarrow H_2S + 4H_2O$

ALLOW *fractions/multiples*

IGNORE *state symbols*

1

(ii) $2I^- \longrightarrow I_2 + 2e^{(-)}$

ALLOW *fractions/multiples*

IGNORE *state symbols*

ALLOW $2I^- - 2e^{(-)} \longrightarrow I_2$

1

(iii) $H_2SO_4 + 8H^+ + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2$

ALLOW

$H_2SO_4 + 8HI \longrightarrow H_2S + 4H_2O + 4I_2$

$SO_4^{2-} + 2H^+ + 8HI \longrightarrow H_2S + 4H_2O + 4I_2$

STEMUP.CO.UK

$SO_4^{2-} + 10H^+ + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2$

$9H_2SO_4 + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2 + 8HSO_4^-$

$9H_2SO_4 + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 8NaHSO_4$

$H_2SO_4 + 8H^+ + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 8Na^+$

$5H_2SO_4 + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2 + 4SO_4^{2-}$

$5H_2SO_4 + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 4Na_2SO_4$

1

(iv) 'Oxidising agent' box ticked

1

(v) $H_2SO_4 + 2NaF \longrightarrow Na_2SO_4 + 2HF$

OR

$H_2SO_4 + NaF \longrightarrow NaHSO_4 + HF$

1

(vi) Fluoride less powerful reducing agent (than iodide)

OR

Fluoride less easily oxidised than iodide

Or reverse argument in either case

***NOT** general group VII trend statement*

***NOT** fluorine/F or iodine/I*

Must be comparative

1

(d) (i) $Cl_2 + H_2O \rightleftharpoons 2H^+ + Cl^- + ClO^-/HCl + HOCl$

***ALLOW** $\longrightarrow$ for $\rightleftharpoons$*

1

(ii) Equilibrium <u>shifts/moves</u> left

1

(Producing) chlorine (which) is toxic/poisonous

Mark independently

1

[13]

Q24.

(a) (i) $\mathbf{2}Cl^- \longrightarrow Cl_2 + \mathbf{2}e^-$

Ignore state symbols

Credit loss of electrons from LHS

Credit multiples

Do not penalise absence of charge on electron

1

(ii) +7 ***OR*** 7 ***OR*** VII ***OR*** +VII

Allow Mn^{+7} and 7+

1

(iii) $MnO_4^- + 8H^+ + 5\mathbf{e}^- \longrightarrow Mn^{2+} + 4H_2O$

STEMUP.CO.UK

Ignore state symbols
Credit loss of electrons from RHS
Credit multiples
Do not penalise absence of charge on electron

1

(b) (i) $Cl_2 + \mathbf{2}Br^- \longrightarrow \mathbf{2}Cl^- + Br_2$

OR

$\frac{1}{2}Cl_2 + Br^- \longrightarrow Cl^- + \frac{1}{2}Br_2$

One of these two equations only
Ignore state symbols

1

(ii) (Turns to) yellow / orange / brown (solution)

Penalise "red / reddish" as the only colour
Accept "red-brown" and "red-orange"
Ignore "liquid"
Penalise reference to a product that is a gas or a precipitate

1

(iii) (Chlorine) gains electron(s) / takes electron(s) / accepts electron(s) (from the bromide ions)

OR

(Chlorine) causes another species (Br^-) to lose electron(s)

Penalise "electron pair acceptor"
Not simply "causes loss of electrons"

1

(c) **M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

$(\mathbf{4}H^+ + \mathbf{4}Cl^-)$

M2 Oxidation state **−1**

Ignore state symbols
Credit multiples
***M2** consequential on HCl or Cl^- which **must** be the only chlorine-containing product in the (un)balanced equation.*
*For **M2** allow Cl^{-1} or Cl^{1-} but **not** Cl^-*

2

(d) **M1 The relative size (of the molecules / atoms)**

Chlorine is smaller than bromine ***OR*** has fewer electrons / electron shells

*For **M1** ignore whether it refers to molecules or atoms.*

OR It is smaller / It has a smaller atomic radius / it is a smaller molecule / atom (or converse)

***CE=0** for the clip for reference to (halide) ions or incorrect statements about relative size*

STEMUP.CO.UK

Ignore molecular mass and M_r

M2 How size of the <u>intermolecular force</u> affects energy needed

Ignore shielding

The <u>forces between</u> chlorine / Cl_2 <u>molecules</u> are weak<u>er</u> (than the forces between bromine / Br_2 <u>molecules</u>)
(or converse for bromine)
OR chlorine / Cl_2 has <u>weaker / fewer / less</u> (VdW) <u>intermolecular forces / forces between molecules</u>
(or converse for bromine)

QoL in M2 *for clear reference to the difference in size <u>of the force between molecules</u>. Reference to Van der Waals forces alone is not enough.*

*Penalise **M2** if (covalent) bonds are broken*

2

[10]

Q25.

(a) **M1 (could be scored by a correct mathematical expression)**

M1 <u>$\Delta H = \sum \Delta H_f$ **(products)** − $\sum \Delta H_f$ **(reactants)**</u>
OR a <u>correct cycle of balanced equations</u>

M2 = 5(−635) − (−1560)

= − 3175 + 1560

(This also scores M1)

M3 = **<u>− 1615</u>** (kJ mol^{-1})
Award 1 mark ONLY for (+) 1615

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

Credit 1 mark for(+) 1615 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with V_2O_5 <u>and</u> 5CaO OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M4 Type of reaction is

- reduction
- redox
- (or accept) <u>V_2O_5 / it / V(V)</u> has been <u>reduced</u>

*In **M4** not "vanadium / V is reduced"*

M5 Major reason for expense of extraction − the answer must be about calcium

<u>Calcium is produced / extracted by electrolysis</u>
OR <u>calcium</u> is <u>expensive to extract</u>

STEMUP.CO.UK

OR calcium extraction uses electricity
OR calcium extraction uses large amount of energy
OR calcium is a (very) reactive metal / reacts with water or air
OR calcium needs to be extracted / does not occur native

QoL

Accept calcium is expensive "to produce" but not "to source, to get, to obtain, to buy" etc.

*In **M5** it is neither enough to say that calcium is "expensive" nor that calcium "must be purified"*

5

(b) **M1**

$2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$

Ignore state symbols

Credit multiples of the equation

M2

(Change in oxidation state) **0** to (+)**3**
OR
(changed by) **+3**

*In **M2** if an explanation is given it must be correct and unambiguous*

2

(c) **M1**

$VCl_2 + H_2 \longrightarrow V + 2HCl$

*In **M1** credit multiples of the equation*

M2 and **M3**

Two hazards in either order

- HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous
- Explosion risk with hydrogen (gas) OR H_2 is flammable

*For **M2 / M3** there must be reference to hydrogen; it is not enough to refer simply to an explosion risk*

*For **M2 / M3** with HCl hazard, require reference to acid(ic) / corrosive / toxic only*

M4

The only other product / the HCl is easily / readily removed / lost / separated because it is a gas *OR* will escape (or this idea strongly implied) as a gas
OR vanadium / it is the only solid product (and is easily separated)
OR vanadium / it is a solid and the other product / HCl is a gas

*In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.*

4

[11]

Q26.

(a) (i) $\mathbf{3}Fe + Sb_2S_3 \longrightarrow \mathbf{3}FeS + \mathbf{2}Sb$

Or multiples.

Ignore state symbols.

1

STEMUP.CO.UK

(ii) $Fe \longrightarrow Fe^{2+} + 2e^-$

Ignore charge on the electron unless incorrect.
Or multiples.
Credit the electrons being subtracted on the LHS.
Ignore state symbols.

1

(b) (i) $Sb_2S_3 + \mathbf{4.5}O_2 \longrightarrow Sb_2O_3 + \mathbf{3}SO_2$

Or multiples.
Ignore state symbols.

1

(ii) SO_3 or sulfur trioxide / sulfur (VI) oxide

Credit also the following ONLY.
H_2SO_4 or sulfuric acid.
OR
Gypsum / $CaSO_4$ or plaster of Paris.

1

(c) (i) **M1 (could be scored by a correct mathematical expression)**

Correct answer gains full marks.

M1 $\Delta H_r = \Sigma\Delta H_f$(**products**) − $\Sigma\Delta H_f$(**reactants**)

OR a correct cycle of balanced equations / correct numbers of moles

Credit 1 mark for +104 (kJ mol^{-1}).

M2 = 2(+20) + 3(−394) − (−705) − 3(−111)

= 40 −1182 + 705 + 333

= −1142 − (−1038)

(This also scores M1)

M3 = **−104** (kJ mol^{-1})

(Award 1 mark ONLY for + 104)

For other incorrect or incomplete answers, proceed as follows:

- *Check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks.*
- *If no AE, check for a correct method; this requires either a correct cycle with 3CO, 2Sb and 3CO_2 OR a clear statement of **M1** which could be in words and scores **only M1**.*

3

(ii) It / Sb is not in its standard state

OR

Standard state (for Sb) is solid / (s)

STEMUP.CO.UK

OR

(Sb) liquid is not its standard state

Credit a correct definition of standard state as an alternative to the words 'standard state'.

QoL

1

(iii) Reduction **OR** reduced **OR** redox

1

(d) Low-grade ore extraction / it

- uses (cheap) scrap / waste iron / steel
- is a single-step process

uses / requires less / low(er) energy

Ignore references to temperature / heat or labour or technology.

1

[10]

Q27.

(a) (i) **M1** (+) 4 **OR** IV

M2 (+) 6 **OR** VI

2

(ii) It / Chlorine has gained / accepted electron(s)

OR

Correctly balanced half-equation eg $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$

Credit 1 or 2 electrons but not lone pair.
The idea of 'reduction' alone is not enough.

1

(b) (i) $\mathbf{6}KI + \mathbf{7}H_2SO_4 \longrightarrow \mathbf{6}KHSO_4 + \mathbf{3}I_2 + S + \mathbf{4}H_2O$

1

(ii) $\mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}e^-$

OR

$8I^- \longrightarrow 4\mathbf{I}_2 + 8e^-$

Ignore charge on the electron unless incorrect.
Or multiples.
Credit the electrons being subtracted on the LHS.
Ignore state symbols.

1

(iii) $H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

STEMUP.CO.UK

OR

SO_4^{2-} + **10**H^+ + **8**e^- ⟶ H_2S + **4**H_2O

Ignore charge on the electron unless incorrect.
Or multiples.
Credit the electrons being subtracted on the RHS.
Ignore state symbols.

1

(c) (i) $Ag^+ + I^- \longrightarrow AgI$ ONLY

Ignore state symbols.
Not multiples.

1

(ii) The precipitate / solid / it does not dissolve / is insoluble / remains

OR a white / cream / yellow solid / precipitate

OR stays the same

OR no (visible / observable) change

OR no effect / no reaction

Ignore 'nothing (happens)'.
Ignore 'no observation'.

1

(iii) The silver nitrate is acidified to

- react with / remove (an)ions that would interfere with the test
  Credit a correct reference to ions that give a 'false positive'.
- prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test
  Do not penalise an incorrect formula for an ion that is written in addition to the name.
- remove (other) ions that react with the silver nitrate
  If only the formula of the ion is given, it must be correct.
- react with / remove carbonate / hydroxide / sulfite (ions)
  Ignore 'sulfate'.

1

(iv) HCl would form a (white) precipitate / (white) solid (with silver nitrate and this would interfere with the test)

*It is not sufficient simply to state either that it will interfere **or** simply that the ions / compounds react to form AgCl*

1

(d) (i) Any **one** from

Ignore 'to clean water'.

- to sterilise / disinfect water
  Ignore 'water purification' and 'germs'.

STEMUP.CO.UK

- to destroy / kill microorganisms / bacteria / microbes / pathogens
  Credit 'remove bacteria etc' / prevent algae.

1

(ii) The (health) benefit outweighs the risk

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

1

(iii) $Cl_2 + H_2O \longrightarrow HClO + HCl$

OR

$Cl_2 + H_2O \longrightarrow \mathbf{2}H^+ + ClO^- + Cl^-$

OR

$\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

Credit HOCl or ClOH
Or multiples.
Credit other ionic or mixed representations.
Ignore state symbols.

1

(e) **In either order - Both required for one mark only**
Credit correct ionic formulae.

NaClO (OR NaOCl) **and** NaCl
Give credit for answers in equations unless contradicted.

1

[14]

Q28.

(a) $Pt|H_2|H^+||Fe^{2+}|Fe$

Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary

Note, allow one mark only for correct symbol in reverse:

$Fe|Fe^{2+}||H^+|H_2|Pt$

Allow dashed lines for salt bridge
Ignore state symbols
Ignore 2 if used before H^+

2

(b) Electron donor
Allow (species that) loses electrons

STEMUP.CO.UK

Do not allow reference to electron pairs

1

(c) Cl_2 / chlorine

If M1 blank or incorrect cannot score M2

1

(Species on RHS / electron donor) has most positive / largest $E^{\ominus}$ / has highest potential

Do not allow reference to e.m.f. or E(cell)

1

(d) (i) Cl / chlorine

1

(ii) Chlorine +1 to chlorine 0

CE if chlorine not identified in part (i)

Allow chlorine +1 to chlorine –1 (in Cl^-)

Allow oxidation state decreases by one OR two

Allow oxidation state changes by –1 OR –2

1

(e) $4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$

OR

$4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$

Allow one mark for any incorrect equation that shows $HOCl \rightarrow Cl_2 + O_2$

Allow multiples

Ignore state symbols

Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ instead of $2H_2O$)

2

(f) (i) e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)

Allow –1.65 (V)

1

(ii) $2Zn + O_2 \rightarrow 2ZnO$

Allow multiples

Ignore state symbols

Do not allow uncancelled species

If more than one equation given, choose the best

1

(iii) **A** / stainless lid

If M1 incorrect or blank CE=0

1

<u>O_2</u> (electrode) has a more positive $E^{\ominus}$ / <u>oxygen</u> (electrode) requires / gains electrons from external circuit

Or reference to the overall equation and a link to electrons going into A

Allow oxygen is reduced and reduction occurs at the positive

STEMUP.CO.UK

electrode

OR Zinc (electrode) has more negative $E^{\ominus}$

Do not allow reference to e.m.f. or E(cell)

1

(iv) (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated

Allow danger from production of gas / oxygen produced / hydrogen produced

1

[14]

Q29.

(a) moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150 / 1000 = 3.195×10^{-4}

1

($Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$) $Cr_2O_7^{2-}$:Fe^{2+} = 1:6

If 1:6 ratio incorrect cannot score M2 or M3

1

moles of $Fe^{2+} = 6 \times 3.195 \times 10^{-4} = 1.917 \times 10^{-3}$

Process mark for M1 × 6 (also score M2)

1

original moles in 250 $cm^3 = 1.917 \times 10^{-3} \times 10 = 1.917 \times 10^{-2}$

Process mark for M3 × 10

1

mass of $FeSO_4.7H_2O = 1.917 \times 10^{-2} \times 277.9 = 5.33$ (g)

Mark for answer to M4 × 277.9

(allow 5.30 to 5.40)

*Answer **must** be to at least 3 sig figs*

Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)

1

(b) (Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)

Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$

OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $FeSO_4.7H_2O$

1

[7]

STEMUP.CO.UK

Q30.

(a) (i) $3CuS(s) + \mathbf{8}HNO_3(aq) \longrightarrow \mathbf{3}CuSO_4(aq) + \mathbf{8}NO(g) + \mathbf{4}H_2O(l)$

1

(ii) **(+) 5**
(+) 2

2

(iii) $\mathbf{4}H^+ + NO_3^- + \mathbf{3}e^- \longrightarrow \mathbf{2}H_2O + NO$

Ignore state symbols.
*Credit multiples of **this equation only**.*
Ignore absence of charge on the electron.

1

(iv) $S^{2-} + \mathbf{4}H_2O \longrightarrow SO_4^{2-} + \mathbf{8}e^- + \mathbf{8}H^+$

Ignore state symbols.
*Credit multiples of **this equation only**.*
Ignore absence of charge on the electron.

1

(b) M1 add <u>scrap / recycled / waste iron (or steel)</u> to the aqueous solution

*If **M1** refers to iron / steel, but does not make it clear in the text that it is "scrap" / "waste" / "recycled", penalise **M1** but mark on.*

M2 the iron is a <u>more reactive</u> metal ***OR*** <u>Fe is a better reducing agent</u>

*Credit zinc or magnesium as an alternative to iron for **M2**, **M3** and **M4** only, penalising **M1***

M3 <u>Cu^{2+} / copper ions</u> are <u>reduced</u> / <u>gain electrons</u>
OR $Cu^{2+} + 2e^- \longrightarrow Cu$
OR <u>copper / Cu is displaced by Fe</u>

Ignore absence of charge on the electron.

M4 $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$ ONLY

*For **M4**, ignore state symbols*

4

[9]

Q31.

(a) $\mathbf{2}Ca_5F(PO_4)_3 + 9SiO_2 + \mathbf{15}C9CaSiO_3 + CaF_2 + \mathbf{15}CO + \mathbf{6}P$

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

STEMUP.CO.UK

Calculations not required

and

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH=CH_2 + H_2O \rightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

Q32.

(a) Ti is not produced

OR

TiC / carbide is produced OR titanium reacts with carbon

OR

Product is brittle

OR

Product is a poor engineering material

Penalise "titanium carbonate"

Ignore "impure titanium"

Credit "it / titanium is brittle"

1

(b) (i) $FeTiO_3 + \mathbf{3}½Cl_2 + \mathbf{3}C \longrightarrow FeCl_3 + TiCl_4 + \mathbf{3}CO$

Ignore state symbols

Credit multiples

1

(ii) $FeCl_3 + TiCl_4 + \mathbf{7}Na \longrightarrow \mathbf{7}NaCl + Fe + Ti$

STEMUP.CO.UK

OR (for example)

$2FeCl_3 + TiCl_4 + \mathbf{10}Na \longrightarrow \mathbf{10}NaCl + 2Fe + Ti$

Ignore state symbols

Credit multiples including ratios other than 1:1

Ignore working

1

(c) Either order

*Penalise reference to incorrect number of electrons in **M1***

M1 The Cu^{2+} / copper(II) ions / they have gained (two) electrons

OR $Cu^{2+} + 2e^- \longrightarrow Cu$

*For **M1**, accept "copper" if supported by correct half-equation or simplest ionic equation*

OR oxidation state / number decreases (or specified from 2 to 0)

Ignore charge on the electron

M2 The Cu^{2+} / copper(II) ions / they have been reduced

*For **M2** do **not** accept "copper" alone*

2

(d) $2O^{2-} \longrightarrow O_2 + \mathbf{4}e^-$

Or multiples including

$\mathbf{3}O^{2-} \longrightarrow \mathbf{1.5}\ O_2 + \mathbf{6}e^-$

Ignore state symbols

Ignore charge on the electron

Credit the electrons being subtracted on the LHS

1

[6]

Q33.

(a) (i) reduction **OR** reduced **OR** redox ***OR*** reduction–oxidation

Not "oxidation" alone

1

(ii) $Fe^{3+} + \mathbf{3}e^- \longrightarrow Fe$

Ignore state symbols

Do not penalise absence of charge on electron

Credit $Fe^{3+} \longrightarrow Fe - \mathbf{3}e^-$

Credit multiples

1

(b) (i) **Because (one of the following)**

CO is not the only product ***OR***

Reference to "incomplete combustion to form CO" does not answer the question

STEMUP.CO.UK

(Some) complete combustion (also)occurs ***OR***

CO_2 is (also) formed

Further oxidation occurs

1

(ii) The <u>enthalpy change</u> / <u>heat (energy) change at constant pressure</u> in a reaction is <u>independent of the route / path taken</u> (and depends only on the initial and final states)

1

(iii) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

For M1, credit correct reference to molecule/s or atom/s

M2 is <u>burned completely</u> / <u>undergoes complete combustion</u> in (excess) <u>oxygen</u>

M3 with <u>all reactants and products / all substances in standard states</u>

For M3

Ignore reference to 1 atmosphere

OR <u>all reactants and products / all substances in normal / specified states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

3

(c) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the ∑)**

Correct answer gains full marks

Credit 1 mark ONLY for –1 (kJ mol^{-1})

M1 $\Delta H_r = \sum \Delta H_f$ (**products**) – $\sum \Delta H_f$ (**reactants**)

Credit 1 mark ONLY for – 27 (kJ mol^{-1}) i.e. assuming value for Fe(l) = 0

OR <u>correct cycle of balanced equations with 2Fe, 3C and $3O_2$</u>

M2 ΔH_r = 2(+14) + 3(– 394) – (– 822) – 3(–111)

= 28 –1182 + 822 + 333

(This also scores M1)

M3 = **(+) 1** (kJ mol^{-1})

(Award 1 mark ONLY for – 1)

(Award 1 mark ONLY for – 27)

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2)*
- *If no AE, check for a correct method; this requires either a correct cycle with 2Fe, 3C and $3O_2$ OR a clear*

STEMUP.CO.UK

statement of M1 which could be in words and scores only M1

3

(d) (i) $C(s) + O_2(g) \quad CO_2(g)$

State symbols essential

Possible to include C(s, graphite)

1

(ii) These two enthalpy changes are for the same reaction / same equation / same reactants and products

Penalise reference to CO_2 being produced by a different route

OR

They both make one mole of carbon dioxide only from carbon and oxygen (or this idea clearly implied)

"both form CO_2" is not sufficient (since other products might occur e.g.CO)

OR

The same number and same type of bonds are broken and formed

1

[12]

Q34.

(a) (i) **M1** **0**

M2 **(+) 5**

Accept Roman V for M2

2

(ii) $I_2 + 10HNO_3 \longrightarrow \mathbf{2}HIO_3 + \mathbf{10}NO_2 + \mathbf{4}H_2O$

Accept multiples

1

(b) **M1** $IO_3^- + \mathbf{6}H^+ + \mathbf{5}I^- \longrightarrow \mathbf{3}I_2 + \mathbf{3}H_2O$

For M1, ignore state symbols

Credit multiples

Accept $2\frac{1}{2}I_2 + \frac{1}{2}I_2$ as alternative to $3I_2$

Electrons must be cancelled

M2 $NaIO_3$ ***OR*** IO_3^- ***OR*** iodate ions ***OR*** iodate(V) ions etc.

For M2 Do not penalise an incorrect name for the correct oxidising agent that is written in addition to the formula.

Accept "the iodine in iodate ions" but NOT "iodine" alone

Accept "the iodine / I in iodate ions" but NOT "iodine" alone

2

(c) (i) Iodine ***OR*** I_2

Insist on correct name or formula

STEMUP.CO.UK

1

(ii) $H_2SO_4 + \mathbf{6}H^+ + \mathbf{6}e^- \longrightarrow S + \mathbf{4}H_2O$

Ignore state symbols

$SO_4^{2-} + \mathbf{8}H+ + \mathbf{6}e^- \longrightarrow S + \mathbf{4}H_2O$

Credit multiples

Do not penalise absence of charge on the electron

1

(d) hydrogen sulfide

OR H_2S

OR hydrogen sulphide

1

(e) (i) $Ag^+ + I^- \longrightarrow AgI$ ONLY

Ignore state symbols

No multiples

1

(ii) The (yellow) precipitate / solid / it does not dissolve / is insoluble

ignore "nothing (happens)"

OR turns to a <u>white solid</u>

ignore "no observation"

OR stays the same

OR no (visible/ observable) change

OR no effect / no reaction

1

(iii) The silver nitrate is acidified to

- react with / remove <u>(an)ions that would interfere</u> with the test

  Ignore reference to "false positive"

- prevent the formation of other <u>silver precipitates / insoluble silver compounds</u> that would interfere with the test

  Do not penalise an incorrect formula for an ion that is written in addition to the name.

- remove (other) <u>ions that react with the silver nitrate</u>

- react with / remove carbonate / hydroxide / sulfite (ions)

  If only the formula of the ion is given, it must be correct

1

(f) (i) An <u>electron donor</u>

Penalise "electron pair donor"

OR (readily) <u>donates / loses / releases / gives (away) electron(s)</u>

Penalise "loss of electrons" alone

STEMUP.CO.UK

Accept "electron donator"

1

(ii) $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$

Ignore state symbols
Do not penalise absence of charge on electron
Credit $Cl_2 \longrightarrow \mathbf{2}Cl^- - \mathbf{2}e^-$
Credit multiples

1

(iii) For M1 and M2, iodide ions are stronger reducing agents than chloride ions, because

Ignore general statements about Group VII trends or about halogen molecules or atoms. Answers must be specific

M1 Relative size of ions

CE=0 for the clip if "iodine ions / chlorine ions" ***QoL***

Iodide ions / they are larger /have more electron levels(shells) (than chloride ions) / larger atomic / ionic radius

CE=0 for the clip if "iodide ions are bigger molecules / atoms" ***QoL***

OR electron to be lost/outer shell/level (of the iodide ion) is further the nucleus

OR iodide ion(s) / they have greater / more shielding

Insist on iodide ions in M1 and M2 or the use of it / they / them, in the correct context (or chloride ions in the converse argument)

OR converse for chloride ion

M2 Strength of attraction for electron(s)

Must be comparative in both M1 and M2

The electron(s) lost /outer shell/level electron from (an) iodide ion(s) less strongly held by the nucleus compared with that lost from a chloride ion

OR converse for a chloride ion

2

[15]

Q35.

(a) (i) $Cu + \mathbf{4}HNO_3 \longrightarrow Cu(NO_3)_2 + \mathbf{2}NO_2 + \mathbf{2}H_2O$

Or multiples
Ignore state symbols

1

(ii) **M1** HNO_3 (+) **5**

M2 NO_2 (+) **4**

Ignore working out

STEMUP.CO.UK

M1 Credit (V)

M2 Credit (IV)

2

(iii) $HNO_3 + H^+ + e^- \longrightarrow NO_2 + H_2O$

OR

$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$

Or multiples

Ignore state symbols

Ignore charge on the electron unless incorrect and accept loss of electron on the RHS

1

(b) (i) **In either order**

M1 Concentration(s) (of reactants and products) remain(s) constant / stay(s) the same / remain(s) the same / do(es) not change

M2 Forward rate = Reverse / backward rate

For M1 accept [ ] for concentration

NOT "equal concentrations" and NOT "concentration(s) is/are the same"

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(ii) **M1**

The (forward) reaction / to the right is endothermic or takes in / absorbs heat

OR

The reverse reaction / to the left is exothermic or gives out / releases heat

M2 depends on correct M1 and must refer to temperature/heat

The equilibrium shifts / moves left to right to oppose the increase in temperature

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves

to absorb the heat OR

to lower the temperature OR

to cool the reaction

2

(iii) **M1 refers to number of moles**

STEMUP.CO.UK

There are fewer moles (of gas) on the left OR more moles (of gas) on the right.
OR there is one mole (of gas) on the left and 2 moles on the right.

M2 depends on correct M1 and must refer to pressure
The equilibrium shifts / moves right to left to oppose the increase in pressure

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves to lower the pressure.

2

[10]

STEMUP.CO.UK

Q1.

(a) This was answered well – nearly all students (83.8%) were able to state two correct oxidation states.

(b) Very few students were able give the first half-equation for the oxidation of chlorine whereas the second half-equation was more regularly correct.

(c) Only some students (23.1%) were able to recall this equation from the specification.

(d) Some students successfully calculated the mass of potassium iodide. However, many did not appreciate that this reaction was not 1:1 and so used the incorrect reacting ratio in their calculations. Many students stated incorrectly that the iodine formed would be observed as purple fumes or as a purple solution. This question discriminated particularly well.

(e) Most students were able both to write the correct equation and calculate the enthalpy change. Only 8.4% of students were unable to score at least one mark.

Q2.

(a) Nearly all students (91.1%) gained both marks here.

(b) Although 73.9% of students scored two marks, common errors here included a failure to convert temperature into kelvin or using inconsistent energy units.

(c) Students found the explanation in this part more challenging and many could not state that the Gibbs free-energy would become more negative. Many students, however, scored the second mark for a correct reference to a change in entropy.

(d) Many students discussed the general principles of homogeneous catalysis or the lowering of activation energy rather than the reaction on the platinum surface. The mark most commonly missed was the idea that the product desorbed from or left the surface of the catalyst. Surprisingly, over 10% of students made no attempt at this question.

(e) 74.4% of students answered this correctly, although a few students thought the oxidation state of N in ammonia was +3.

(f) Many students gave hydrogen as the other product or failed to balance an equation in which water was the other product.

Q3.

(a) Only 11.3% of students scored both marks here; sometimes Fe^{2+} was chosen but students could not explain their choice. The most common incorrect answer was Zn^{2+}.

(b) Just over three-quarters of students could give the oxidation state.

(c) The structure was often given, incorrectly, as a mirror image and the type of isomerism as optical; only 37.2% of students scored both marks.

STEMUP.CO.UK

(d) This was poorly answered, with only just over a third of students giving the correct equation.

(e) Over half of the students (55.6%) gave the correct equations; incorrect equations included charged vanadium species. Surprisingly, 12% of students were unable to make any attempt at this question.

Q4.

(a) Students showed admirable ability to calculate the oxidation states and 71.8% of them gained both marks.

(b) This question was well answered with 44.6% of students gaining the mark.

(c) 62.4% of students gained the mark for this familiar half-equation.

(d) This question discriminated better than the previous two part-questions; surprisingly, 8.5% of students did not even attempt it.

(e) 56.3% of students were successful in gaining this mark.

(f) Despite the challenging mole ratio, this question was answered really well. The familiar context of the question requiring manipulation of concentrations and volumes proved to be more accessible. The final answer required unfamiliar units and failure to grasp that aspect often limited students to three marks.

Q5.

Although 47.8% of students scored here, the three distractors all drew significant attention.

Q6.

Only 42.2% of students selected the correct answer. Perhaps many students did not appreciate that a range of sulfur-based products are formed in the reaction.

Q7.

(a) The oxidation states were well known, with 92.2% of students gaining both marks; +7 was the commonest wrong answer for the nitrate ion.

(b) Just under half of students could identify the weakest reducing agent.

(c) “Nitrate ions” was a common insufficient answer, and sulfuric acid a common incorrect answer. Only the very best students scored mark point two; the common incorrect answer was that the E^{θ} for NO_3^- was more positive than the E^{θ} for copper. The equation was often unbalanced, but the cell emf was generally calculated correctly.

Q17.

Half-equation manipulation was well done in **(a)** and the mole calculation in **(b)** elicited many good answers. Answers to **(c)** were sometimes poorly expressed or incomplete.

Q18.

STEMUP.CO.UK

Students appeared to understand **(a)** but, again, answers were often penalised for poor chemical expression. Surprisingly, **(b)** generated some unusual responses, possibly because students were looking for too complex an answer! **(c)** was too generously marked by a significant number of schools – the need to extract a sample to prevent contamination or to state what the pH probe should record was often overlooked and had to be penalised on moderation. Part **(d)** was well done but **(e)** resulted in a few contradictory answers as students struggled to explain the process. In **(f)**, despite the unfamiliar context, there were many excellent answers but in **(g)** explanations were occasionally too brief and did not cover both marking points. Answers to the final question, **(h)**, identified those students who had carried out recrystallisation and had thought about the background principles involved.

Q19.

This question was answered poorly. Even the half equation in (a) was usually not answered correctly and the more challenging equations in (b) and (c) were only seen from the better students. In (d) the explanation that iodide ions are oxidised wasn't seen very often but a reasonable proportion of students scored some marks on this question.

Q20.

Usually well answered.

Q22.

It was surprising to see that this question was answered poorly but it did give further evidence that redox ideas are not well understood by large numbers of students at this level.

Q23.

In a definition of electronegativity students must make it clear that they are referring to the attraction between the nucleus and the shared pair of bond electrons. Most students were awarded the first mark but many answers were too vague in their references to gain the second mark. Most of the rest of this question was well answered although there were some issues with balancing charges in the redox equations.

Very few students showed the acids formed in part (d)(i) as being dissociated and this, in turn, seemed to make part (d)(ii) harder than expected because many students failed to spot that addition of acid would shift the equilibrium to the left and so produce toxic chlorine gas. Although there was no specific reference to le Chatelier in the question (which would have given a more specific clue) the stem of part (d) did refer to an equilibrium mixture and this was intended to point students in the right direction.

Q24.

This was a relatively straightforward start to the paper, but the usual errors were made in balancing equations. The idea of oxidation state is relatively well understood. In part (d), students demonstrated a lack of clarity in what happens during the process of boiling, often alluding to bond breakage and rarely referring to the forces between molecules.

Q25.

This question provided a range of challenges. The calculation in part (a) was answered well and the necessity to focus on either the extraction or the reactivity of calcium was understood by many. In part (b), many students were unable to write a correct formula

either for iron(III) oxide or for aluminium oxide and there was often a lack of clarity when stating the change in oxidation state of aluminium in this reaction. The equation in part (c) was generally done well and many students correctly linked an appropriate hazard to each of hydrogen and hydrogen chloride. The idea that the HCl could escape as a gas and the only other product was vanadium, was necessary to gain the final mark.

Q26.

Too many students had problems writing and balancing the equations in each of parts (a)(i), (a)(ii) and (b)(i). The calculation in part (c)(i) was straightforward and most students scored all 3 marks although errors were seen in simple mathematical operations. The remainder of the question was also relatively high scoring.

Q27.

Part (a) was answered well but part (b) proved more demanding. Only about one-third of students were able to balance the equation in part (b)(i) and only about half of students gave correct half-equations in parts (b)(ii) and (b)(iii). The halide ion analysis in part (c) was well known with the lowest scoring part being (c)(iv), with many having failed to recognise that it is insufficient to simply state that AgCl is formed. Any question involving NaClO is always demanding and part (e) was no exception with less than half of the students scoring the mark.

Q28.

Few correct answers were seen to part (a). Some students did not comply with the convention of placing the hydrogen electrode on the left when measuring the standard electrode potential. Some failed to include all the phase boundaries, putting a comma between H_2 and H^+ instead of a solidus, whilst other students included too many phase boundaries at the extremities or an incorrect, additional platinum connected to iron. Parts (b) and (c) were answered well. All the elements were chosen by students in part (d)(i) and where the correct answer of chlorine was selected, the oxidation states in part (d)(ii) and the equation in part (e) were usually correct. It was pleasing to find that answers to parts (f)(i) and (f)(ii) were usually correct. Most students identified the positive electrode correctly in part (f)(iii) but only the highest-scoring students used an appropriate electrode potential from the table to explain their answer.

Q29.

Many good answers were seen to part (a) in which full marks were scored. However, most students used an incorrect ratio for the amount, in moles, of iron(II) that reacts with one mole of dichromate ions. For these students, the maximum they could score was three out of a possible five marks. In part (b), many students suggested, correctly, that the impurity was likely to be a reducing agent but very few went on to explain that the impurity must react with more moles of dichromate than would the same mass of $FeSO_4.7H_2O$.

Q30.

The balancing in part (a)(i) proved demanding and only approximately 60% scored this mark. The oxidation states in part (a)(ii) were high scoring with the vast majority of students gaining two marks. However, the construction of redox equations in parts (a)(iii) and (a)(iv) were of much higher demand and only 28% and 21%, respectively, gained these marks.

Few students scored full marks in part (b) despite its more open-ended approach to this topic. The question required recognition that this was about the use of scrap iron, but one

mark was possible even for those students who chose an expensive method such as electrolysis.

Q31.

Balancing the equation in part (a) taxed some students but most were able to score at least one mark in part (b). There was a need for students to use correct chemical terminology in part (d), requiring, for example, reference to the "addition of water" in part (d)(ii). It was surprising to see how many made simple errors in the relatively straightforward part (d)(iii), for example, naming the alcohol as propanol rather than propan–2–ol.

Q32.

Most students have some familiarity with the extraction of titanium and many were able to apply their ideas in the novel context presented in part (b). Part (c) produced many good answers but the equation in part (d) was only answered correctly by the best students.

Q33.

The thinking required in part (b)(i) proved too much for many and only a few were able to state that, in practice, CO is not the only product and that some complete combustion to form CO_2 would occur. The answer of +1 kJ mol^{-1} was seen frequently in part (c), but some were disconcerted by this value and sought to find an alternative. State symbols were often missed in part (d)(i) and a clear statement in part (d)(ii) that the same reaction occurs for the two specified standard enthalpies was not well understood.

Q34.

Many very good answers were seen throughout this question. In part (b), the oxidising agent was not well answered by some. In parts (c), (d) and (e), the answers requiring observations suggest that not all students have had the chance either to see or to perform these simple experiments. Part (f) was well answered with the correct use of chemical names and terminology.

Q35.

Candidates struggled to balance the equation in part (a)(i) with 30% failing to complete it correctly. Part (b)(i) is straight from the specification and two thirds of candidates did not have a problem. In parts (b)(ii) and (b)(iii) candidates demonstrated that they are learning how to express their ideas with clarity and some very good answers were seen. Some answers suffered from contradictory statements while others included statements that were open to different interpretations.

STEMUP.CO.UK