1. (a) (i)
- LiCl red/scarlet/crimson/carmine red **(1)**
- NaBr orange/yellow **(1)**
- KI lilac/purple/mauve/pink/violet/lavender **(1)** 3

(ii)
- Excited electrons **(1)**
- Move down energy levels **(1)** 2

(b) (i)
- LiCl - white/steamy fumes
- NaBr - brown/orange vapour or liquid
- Kl - purple vapour / dark solid or liquid or residue 4

(ii) $LiCl(s) + H_2SO_4(l) \rightarrow \rightarrow LiHSO_4(s) + HCl(g)$
formulae **(1)**, states **(1)**

or $2LiCl(s) + H_2SO_4(l) \rightarrow \rightarrow Li_2SO_4(s) + 2HCl(g)$
formulae **(1)**, states **(1)** 2

[11]

2. (a) (i) Loss of electrons 1

(ii) A substance which gains/removes/accepts electrons 1

(iii)
- Chlorine (is stronger oxidising agent)
- So it can accept electrons from Br^-/
  so it can displace Br^-/ so can oxidise Br^- 2

(b) (i) $3OCl^- \rightarrow \rightarrow ClO_3^- + 2Cl^-$
formulae + charges **(1)**, balancing **(1)** 2

(ii) Disproportionation 1

(c) (i) SO_2: +4
SO_4^{2-}: +6 2

(ii) Oxidised because oxidation number of S becomes more positive/sulphur loses electrons 1

(iii)
- Starch/any named non polar solvent: hexane, chloroform, volasil
- Blue-black/purple 2

[12]

3. (a) (i) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$ **(1)**
or
$2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$ **(1)** 1

(b) (i) add silver nitrate (solution) / correct formula $AgN0_3$ (aq) **(1)**

white ppt /solid **(1)**
soluble in dilute ammonia /ammonia solution **(1)**
or
add lead nitrate/ethanoate (solution) **(1)**
white ppt. **(1)**
soluble in hot water **(1)**
Any feasible correct chemical method can score the marks here 3

(ii) dissociates /reacts/lionises/changes into ions (as it dissolves) **(1)**
forming H^+ ions / H_3O^+ ions/ donates a proton to water.
This makes the solution an acid **(1)** 2

(i) damp litmus paper **(1)** bleached **(1)**
or
damp starch-iodide paper **(1)** goes blue **(1)**
Displacement acceptable 2

(ii) [+4] [−1] **(1)**
[+2] [−1] [0] **(1)**
positive charge not essential 2

(d) (hydrogen) iodide is more easily oxidized / loses electrons more easily than (hydrogen) chloride **(1)**
because larger (than chloride) **(1)**
Could argue from the reducing power of the iodide / chloride for the first mark 2

[12]

4. (a) (i) +7/7+ /VII 1

(ii) +7/7+ /VII 1

(b) (i) $Sn^{2+} \rightarrow Sn^{4+} + 2e^{(-)}$ *OR* $Sn^{2+} - 2e^{(-)} \rightarrow Sn^{4+}$ **(1)**

$I_2 + 2e^{(-)} \rightarrow 2I^-$ **(1)** 2

(ii) $Sn^{2+} + I_2 \rightarrow Sn^{4+} + 2I^-$
IGNORE state symbols 1

[5]

5. (a) $H_2SO_4 + NaCl \rightarrow NaHSO_4 + HCl$/

$H_2SO_4 + 2NaCl \rightarrow Na_2SO_4 + 2HCl$ 2

Either version
State symbols (Ignore these)
Multiples

$H_2SO_4 + NaCl \rightarrow NaSO_4 + H_2\ Cl$ (0)

Correct formulae (1) Balanced (1)

Second mark depends on first being correct

4 correct formulae with an additional existing molecule eg H_2, SO_2 Max 1

(b) (i) Sulphur: from +6 to +4 **(1)**
Bromine: from –1 to 0 **(1)** 2

Accept sign after value,
Roman numerals

Incorrect signs

(ii) Increase in ox number of bromine = 2 × 1 / 2 **(1)**
One S decreases in ox number by 2 **(1)**
Must be clear that one S atom is unchanged/only one S changes for second mark.
[Look for oxidation no. written under elements in equation] 2

*Accept increase in oxidation number of Br = decrease in oxidation number of S, without specifying values **(1)***

Reject explanations in terms of electrons

(c) (i) Going down group
Number of electrons increases **(1)**

Accept reverse argument going up group

Reject arguments based on quantum shells.

So Van der Waals force (between molecules) increases **(1)**
Ignore comments on radius of atom 2

Reject vdw for Van der Waals

(ii) Boiling point between 200 and 300 (K) **(1)**
–73 to +27 if value quoted in °C
Hydrogen bonding is present **(1)**
Stronger forces between molecules /stronger intermolecular forces (than in other hydrogen halides.) **(1)** 3

Accept B pt 155 – 175(K) with explanation that there are fewer electrons in HF for maximum 1 mark.

*Accept boiling point in correct range, with comment on **much** stronger dipole in HF and stronger intermolecular forces **(2)***

[11]

6. (a) Any statement that means the number gets less
Eg
Decrease (in oxidation number of an element)
Reduction of ON
Lowering of ON
ON becomes more negative
ON becomes less positive 1

Reject 'just' Gain of electrons

(b) (i) $2NaBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}\ NaHSO_4 + SO_2 + Br_2 + \mathbf{2}H_2O$
OR
$2NaBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}\ NaHSO_4 + \ldots SO_2 + \ldots\ Br_2 + \mathbf{2}H_2O$
OR
$2NaBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}\ NaHSO_4 + 1SO_2 + 1Br_2 + \mathbf{2}H_2O$ 1

(ii) H_2SO_4 : +6 / 6 / VI / 6+
HSO_4^-: +6 / 6/ VI / 6+
SO_2 : +4/4/IV / 4+
H_2S : –2 / –II / 2–
All four correct 2 marks
Any 3 correct 1 mark 2

Reject superscript + e.g S^{6+}

(iii) Change in ON of S increases down (halide) group **(1)**
Link all three changes to actual numbers with halide **(1)**
Consequential on answers to part(ii) 2

Correct answer referring to only two halides scores 1 mark

If ref to halogens lose second mark

[6]

7. (a) (i) $Br_2(aq) + H_2O(l) \rightleftharpoons 2H^+(aq) + Br^-(aq) + BrO^-(aq)$
formulae **(1)**
balancing (ignore state symbols) **(1)** 2

Accept $\rightleftharpoons$ *$H^+(aq) + Br^-(aq) + HBrO(aq)$/ BrOH*
$H^+(aq) + BrO^-(aq) + HBr(aq)$
If HBr + HBrO, H^+ must be crossed out

(ii) reaction is reversible/equilibrium (reaction)
can go backward and forward/can go both ways/occurs in both directions 1

Accept reversable ***(1)***

(iii) bromine has been both oxidised and reduced **(1)**
↑
must mention bromine (Br/Br_2 for first mark)
from 0 to +1 and –1 **(1)** 2

Accept Br oxidation number both increased and decreased /goes up and down

Reject bromine goes to +1 and –1
must show from 0
Reject arguments based on OILRIG
Incorrect identification of ox/red i.e. ox is 0 → –1

(iv) $Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$
formulae **(1)**
balancing and state symbols **(1)**
second mark dependent on first unless correct but non ionic equation given
$Cl_2(g) + 2KBr(aq) \rightarrow 2KCl(aq) + Br_2(aq)$ 2

Accept $Br_2(l)$
Accept multiples

Reject $Cl_2(aq)$
Reject Br_2 (g) $Br^2(aq)$

(b) (i) Sulphur from +4 to +6 /4+ to 6 + /4 to 6 **(1)**
Bromine from 0 to –1 **(1)**
Accept name or symbol (S or Br or Br_2) 2

Accept oxidation and reduction transposed but correct numbers
1 (out of 2)
Elements correctly identified but incorrect numbers
1 (out of 2)
Accept sulfur, sulpher, sulfer

(ii) $Br_2 + 2H_2O + SO_2 \rightarrow 4H^+ + 2Br^- + SO_4^{2-}$ 1

Accept multiples

[10]

8. A

[1]

9. (a) (i) Procedure: Only one titration carried out/ no check on accuracy of titration
OR
1000 cm^3 volume to large to fit in titration flask **(1)**

Recording: Did not record burette readings to 0.05 cm^3 /1 decimal place / sufficient precision / recording only one significant figure in a titration reading **(1)** 2

(ii) 4.65×10^{-5} / 4.7×10^{-5} / 0.0000465 / 0.000047 (mol) 1

(iii) 2.3×10^{-5} / 0.000023
OR candidates answer to (ii) divided by 2 1

(iv) 2.3×10^{-5} / 0.000023 mol dm^{-3}
OR candidates answer to (iii) 1

(b) (i) QWC

Redox as chlorine removes/gains electrons from the metal (and is reduced) **(1)**
And metal gives/loses electrons to the chlorine (and is oxidised) **(1)**

Redox is essential in order to score both marks
The gain / loss of electrons can be awarded from two ionic half equations**.** 2

(ii) Chlorine is (highly) toxic/poisonous/irritant
OR chlorine has an unpleasant smell **(1)** 1

(iii) $Ca(ClO)_2$ **(1)** 1

(iv) QWC

Cl is oxidised from +4 (in ClO_2) to +5 (in $HClO_3$) **(1)**
and is reduced (from +4) to +1 (in HClO) **(1)** 2

(c) **QWC**

Any of the five points below as long as they are logically connected and use correct scientific terminology plus 1 mark for an equation to a maximum of 6 marks.

- CFCs are greenhouse gases
- because their dipole moment changes when they vibrate
- and so contribute to global warming
- depletion of the ozone layer
- causes less ozone to absorb UV radiation (from the sun) / increase in UV reaching the earth's surface
- causes skin cancer / mutations
- CFCs (decompose photolytically to) produce free radical chlorine atoms/ Cl radicals
- Recognition that one Cl radical can cause the destruction of many thousands of ozone molecules / or mention of chain reaction

Equations $Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$

$ClO^{\bullet} + O^{\bullet} \rightarrow Cl^{\bullet} + O_2$

Either equation or other relevant equation **(1)** 6

[17]

10. (a) formal charge 1

an atom would have in a compound if ionic 1

OR

number of electrons lost or gained 1

control of / used for bonding 1

(b) (i) 0 +1 –1 (ignore everything else) 1

(ii) One of the chlorines in each molecule (0 to +1) has lost an electron / been oxidised 1

The other chlorine in the chlorine molecule has gained an electron / been reduced to –1 1

a simple statement / definition of disproportionation max 1

(c) reacts / changes / dissociates / ionises /
HCl donates a proton to the water 1

H^+ (aq) or H_3O^+ (aq) ions 1

(d) white **precipitate (1)** soluble in ammonia. **(1)** chloride cream **ppte (1)**
slightly soluble in ammonia **(1)** bromide yellow **ppte (1)**
insoluble in ammonia **(1)** iodide 6

if only 3 colours without any mention of ppte max **1** out of **3**

[13]

11. (a) B **(1)** 1

(b) Limewater turns milky ∴ CO_2 **(1)**
$MgCO_3$ decomposes on heating to CO_2 ∴ label correct / equation **(1)** 2

(c) Substance on wire in flame **(1)** <u>not</u> burn or heat (in test tube)
(Pale) green flame for barium **(1)**
No colour for magnesium **(1)**
or
add dilute sulphuric acid **(1)**
barium hydroxide does not dissolve **(1)**
magnesium hydroxide dissolves / forms colourless solution **(1)**
or
Valid <u>chemical</u> test 3

(d) (brown gas is) nitrogen dioxide **(1)**
(gas relights a glowing splint) oxygen **(1)**
$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$
species **(1)** balance **(1)** 4

[10]

12. (a) (i) Ca brick red or orange red, Ba (apple) green **(1)** each 2

(ii) electrons excited / promoted **(1)**
fall to lower energy level / orbital **(1)**
give out energy in the visible region / in form of light **(1)** 3

(b) $2Ba(NO_3)_2 \rightarrow 2BaO + 4NO_2 + O_2$ **(2)**
species **(1)** balance **(1)** 2

(c) (i) ability (of a cation) to distort / change shape of **(1)**
the electron cloud around an anion **(1)** 2

(ii) Size /radius /ionic radius **(1)** charge **(1)** 2

(iii) Mg^{2+} / magnesium **ion** smaller than Ba^{2+}/ barium **ion**
or
Mg^{2+} has higher change density **(1)**
Polarising power increases/ Mg^{2+} able to polarise the nitrate ion more effectively than Ba^{2+} **(1)**
this weakens the bonds in the nitrate / bonds in nitrate more easily broken **(1)** 3

[14]

13. (a) (i) $2Ca + O_2 \rightarrow 2CaO$ **(1)** 1

(ii) $Na_2O + H_2O \rightarrow 2NaOH$ **(1)** 1

(iii) $Na_2O + 2HCl \rightarrow 2NaCl + H_2O$
Species **(1)** Balancing **(1)** 2

(b) (Thermal stability) increases **(1)** (with some attempt at a reason)

(cat)ion size increases / (cat)ion charge density decreases **(1)**
polarises or distorts carbonate ion / anion / electron cloud less. **(1)** 3

[7]

14. $O^{2-} + H_2O \rightarrow 2OH^-$
IGNORE state symbols
ALLOW if Mg^{2+} shown on both sides 1

[1]

15. (a) (i) $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$
IGNORE state symbols 1

Accept multiples

Reject $Ba + H_2O \rightarrow BaO + H_2$

(ii) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$
OR
$2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$
IGNORE state symbols 1

Accept multiples

Reject $HNaSO_4$

(b) (i) Green/pale green/apple green 1

Accept yellow-green

Reject any mention of blue e.g. blue green OR any other colour

(ii) Red 1

Accept deep/dark red / carmine/crimson /scarlet

Reject lilac

Reject any mention of lilac e.g. lilac-red OR any other colour

(c) **Electrons** (absorb heat/energy) and are promoted to **higher** energy levels **(1)**

as they **drop** back/down **(1)**

Emit radiation (of characteristic colour)
OR emit light **(1)** 3

Accept "excited/go" instead of "promoted"

Accept "orbitals/shells" instead of "energy levels"

Reject if any reference to absorption spectra
*e.g. light absorbed **(0)***

*Reject (produce) colours **(0)***

(d) Percentage oxygen (= 45.1) **(1)**
÷ Ar **(1)**
Empirical formula = KO_2 **(1)**

e.g.
Percentage of oxygen = 45.1 **(1)**

K	O	
54.9	45.1	**(1)**
39	16	
1.41	2.82	

KO_2 (1) 3

*Accept use of atomic numbers **2 max***

*Accept use of "O_2" Mr ~ 32 but only if give formula KO_2 (for **3 marks**)*

Reject mole calculation – then inverted, no consequential marking on formula

[10]

16. (a) (i) $4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$
Species **(1)**
Balance **(1)**
Not stand alone conditional on correct species 2

Accept or fractions/ multiples

(ii) $2CsNO_3 \rightarrow 2CsNO_2 + O_2$
Correct balanced equation 1

Accept or fractions/ multiples

(b) (i) There must be a comment about both barium and calcium to score both marks
Barium would react to produce a (colourless)/(clear) solution does not give a ppt./ clear **(1)**

Allow Ba and Ca in argument
*Accept barium **hydroxide** dissolves*

Reject goes colourless

Calcium would go cloudy /give (white) ppt. **(1)**
E.g. Calcium would go cloudy but barium (goes) clear **(2)** 2

Reject other colours

(ii) Insoluble/ solid/layer / coating of **barium sulphate** formed **(1)** allow equn with $BaSO_4(s)$
Must say what the coating is since question says use information in table

Which prevents **acid** getting to surface (of barium) **(1)**
2nd mark conditional on 1st need some idea that a substance is formed that generates a barrier to further reaction 2

If candidate uses word ppt must be clear that this is on the surface of the barium or causes interference

Reject $BaSO_4$ unreactive

Reject barium disappears

Any reference that implies barium all used up or was a very small piece or acid not in excess or reaction over scores zero

Reject references to other layers such as oxide/hydroxide

(c) Insoluble **(1)** 1

(d) $Ca(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$
1 mark for equation
1 mark for state symbols 2

Accept state symbol mark for correct molecular equation

*$Ca(s) + 2HCl(aq) \rightarrow$ **$CaCl_2(aq)$** + H_2 (g) scores **(1)***

[10]

17. (a) (i) (pale) green 1

Accept apple green

Accept yellow(y) green

Reject blue green

(ii) Crimson 1

Accept red
Accept scarlet
Accept carmine
Accept depth of red colour e.g.
Dark red
Deep red
Pale red
Light red
Bright red

Reject red with any other colour e.g.
Brick-red
Orange-red
Yellow-red
Magenta

(b)

Ba	O
$\frac{81.1}{137}$	$\frac{18.9}{16}$
= 0.592	= 1.18
1	2

(1)

*Accept dividing by 32 scores **(0) unless** their table is headed by O_2, then answer BaO_2 scores **(1)***

Correct working leading to answer BaO_2 **(1)**

*but if this is the case BaO scores **(0)***

Working must be shown and final formula given for 2 marks
BaO_2 without working 1 mark 2

*Reject any answer dividing by atomic number **(0)***
This leads to Ba_2O

(c) (i) $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$

Ignore state symbols even if they are wrong 1

Accept multiples

Reject equations based on BaO

(ii) • Gets warm

Accept heat produced

• Effervescence/fizzing/ bubbles/mist

Accept bubbles of hydrogen

• Ba sinks/moves up and down /Does not float

Give one mark for observation from each bullet point to max of 2

3 answers given, one wrong scores **(1)**
3 answers given, two wrong scores zero

Ignore mention of Steam/steamy fumes
Ba gets smaller
Ba disappears
Goes cloudy / precipitate
Gas/hydrogen evolved is not an observation 2

Reject reference to flame
Reject melts
Dashes about on surface are wrong answers

(iii) *Red litmus* (goes) blue/ "(→) blue"
and
blue litmus unchanged/stays blue/no effect/nothing 1

[8]

18. B

[1]

19. B

[1]

20. C

[1]

21. D

[1]

22. A

[1]