1. (a) (i) Ca^+ is smaller than Ca/ proton : electron ratio in Ca^+ > Ca **(1)**
greater attraction from nucleus **(1)** 2

(ii) "oxide" ion, O^- and electron are both negative **(1)**
hence energy is required to overcome repulsion **(1)** 2

(b) completes Born-Haber cycle showing 1st IE↑ 2nd IE↑ 1st EA ↓ 2nd EA↑
and LE↓**(1)(1)(1)** (lose 1 mark for each error/omission)
LE = –**(1)**3451 kJ mol^{-1} **(1)** 5

(c) differences in size of lattice enthalpies linked to ionic sizes/attraction using **more/less exothermic** rather than bigger or smaller. **(1)**

Mg^{2+} is smaller/Mg^{2+} has greater charge density**(1)**
hence has stronger attraction for O^{2-} **(1)** 3

[12]

2. (i) 525 kJ mol^{-1} **(1)** 1

(ii) 193.6 J K^{-1} mol^{-1} **(1)** 1

(iii) uses $\Delta G = \Delta H - T\Delta S$ **(1)**
To be feasible, $\Delta G = 0$ or $\Delta G < 0$ **(1)**
minimum $T = \Delta H / \Delta S$ **(1)**
Converts ΔS from J to kJ/÷1000 or converts ΔH from kJ to J **(1)**
2712 K/ 2438 °C / 2439 °C **(1)** *(units essential)* 5

[7]

3. (i) oxidation: $Fe \rightarrow Fe^{2+} + 2e^-$ **(1)**
reduction: $V^{3+} + e^- \rightarrow V^{2+}$ **(1)** 2

(ii) E_{cell} = 0.18 V **(1)** 1

[3]

4. (i) system **III** × 2 and reversed + system **IV (1)**
$2H_2 + O_2 \rightarrow 2H_2O$/
$H_2 + ½O_2 \rightarrow H_2O$ **(1)** 2

(ii) advantages:
only H_2O formed/ non-polluting
greater efficiency **(1)**

disadvantages:
H_2 difficult to store **(1)**
H_2 difficult to manufactured initially /
limited life cycle of H_2 adsorber/absorber **(1)** 4

[6]

5. **Definition – maximum 3 marks**

$Mg^{2+}(g) + 2Cl^{-}(g) \rightarrow MgCl_2(s)$ **(1)**
The enthalpy change that accompanies the formation of
one mole of a solid (compound) **(1)**;
from its constituent gaseous ions **(1)**

Allow *marks from an equation*
Allow *energy released / energy change*
Not *energy required*
Allow *ionic compound / salt*

Born-Haber cycle – maximum 5 marks

Correct formulae on cycle **(1)**
Correct state symbols **(1)**
Use of 2 moles of Cl(g) ie 246 **(1)**
Use of 2 moles of $Cl^{-}(g)$ 1.e. 698 **(1)**
-2526 kJ mol^{-1} **(1)**

Every formula must have the correct state symbol at least once
Allow *-2403 / -2875 (2)*
Allow *-2752* ***(1)***
Unit ***required***

Comparison – maximum 3 marks

Any three from

Na^+ has a larger radius than Mg^{2+} / ora **(1)**
Br^- has a larger radius than Cl^- / ora **(1)**
Na^+ has a lower charge than Mg^{2+} / ora **(1)**
Strongest attraction is between Mg^{2+} and Cl^- / $MgCl_2$ has the strongest attraction between its ions / ora **(1)**

Penalise the use of incorrect particle only once within the answer.
Penalise it the first time an incorrect particle is mentioned

Or

Na^+ has a lower charge density than Mg^{2+} / ora **(1)**
Br^- has a lower charge density than Cl^- / ora **(1)**
Strongest attraction between ions which have the highest charge density / $MgCl_2$ has the strongest attraction between its ions / ora **(1)**

And QWC

One mark for correct spelling, punctuation and grammar in at least two sentences **(1)** 12

[12]

6. (a) Emf/voltage/potential difference (of electrochemical cell) 1
comprising a (Cu/Cu^{2+}) half cell combined with a standard hydrogen electrode 1
1 atm, 1 mol.dm^{-3}, 298K (all 3 needed but can transfer mark if stated in (b)) 1

(b) Salt bridge and voltmeter 1
Platinum electrode dipping into 1 mol dm^{-3} H^+ 1
Hydrogen gas feed 1
(Accept a suitable alternative standard electrode)

[6]

7. (a) (i) Stainless steel + corrosion resistance or alloys for tools + hardness or other named alloy/use/property 1
Allow chrome plating with attractive or barrier to corrosion

(ii) Chromium $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ (allow….$4s^1 3d^5$) 1

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

$Cr_2O_7^{2-}$ / Cr^{3+} has more positive electrode potential 1

Therefore $Cr_2O_7^{2-}$ is the stronger oxidising agent which oxidises Fe^{2+} to Fe^{3+} (ora) 1

(ii) Emf = (+) 0.56 V 1

[6]

8. (i) $SO_4^{2-} \rightarrow H_2S$: S from +6 to –2 **(1)**

$I^- \rightarrow I_2$: I from –1 to 0 **(1)** 2

(ii) $10H^+ + SO_4^{2-} + 8I^- \rightarrow 4I_2 + H_2S + 4H_2O$ **(1)** 1

[3]

9. (a) (i) Ionisation energy refers to removing electrons that are attracted to the nucleus / energy needed to overcome the force of attraction between outer electrons and nucleus **(1)** 1

(ii) Electron affinity involves an electron (being gained) experiencing attraction to the nucleus **(1)** 1

(b) (i) Correct state symbols **(1)**;

Allow *1 error or omission in state symbols.*
Providing formula has correct state symbols once in cycle this is sufficient

Correct formula **(1)**;

Correct cycle with labelling or energy values **(1)** 3

(ii) = +178 + 249 + 798 + (–141) + 1150 + 590 + (–3459) **(1)**

= –635 kJ mol^{-1} **(1)** 2

Final answer must have correct units
+635 kJ mol^{-1} scores 0

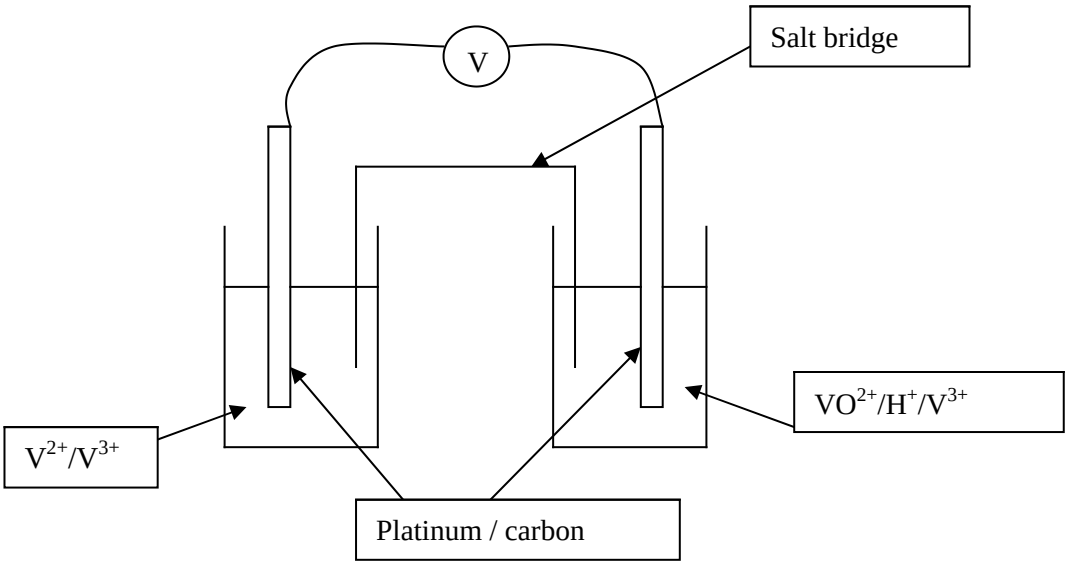
(iii) Ionic radius of iron(II) less (than that of calcium ion) / charge density of Fe^{2+} greater (than that of Ca^{2+}) /. ora **(1)** 1

[8]

10. (a) VO_2^+ 1

(b) (i) B and D 1

(ii)



Allow ecf from (b) (i)
Solutions can be reversed. 4

(iii) 298 K / 25 °C temperature
all solutions 1 mol dm^{-3}
Both needed for 1 mark. Ignore any reference to pressure 1

[7]

11. (a) A = Platinum(electrode)
B = H^+(aq) / HC*l*(aq) / other suitable acid
C = Voltmeter / galvanometer
D = Cl_2(g)
State symbols needed for B and D
All correct = 2, 3 correct = 1 2

(b) (i) Arrow marked on or close to wire via voltmeter pointing from hydrogen half cell to chlorine half cell 1
Electrons flow to half cell with more +ve standard electrode potential 1

(ii) Pressure = 1 Atm / 100 kPa
Temp = 298 K / 25°C
Concentration = 1 mol dm^{-3}
All 3 correct = 2 marks 2 correct = 1 mark 2

(c) The standard electrode potential for ClO_3^- / ½Cl_2 is more positive than that of ½ Cl_2 / Cl^- 1

ClO_3^- has a greater tendency to gain electrons than Cl_2 / ClO_3^- is a better oxidising agent than Cl_2 1

Alternative:
Because $E^{\ominus}$ is positive, the reaction will go from left to right therefore ClO_3^- is reduced so it must be a better oxidising agent than chlorine.

[8]

12. (a) Atomisation of Na = (+)218 / 2 × (+) 109 **(1)**;
Ionisation of Na = (+)990 / 2 × (+)495 **(1)**;
Any other two correct enthalpy changes **(1)**;
Last two correct enthalpy change **(1)** 4

(b) –791 + 141 – 247 – 990 – 218 – 416 **(1)**;
–2521 **(1)** 2

Allow *ecf from part (a) e.g. –2026 if only 1 mole of Na → Na^+*
–2412 if only 1 mole of
Na (s) → Na (g)
–1917 if only 1 mole of Na throughout
Allow *full marks for –2521 with no working out*

(c) Calcium chloride **(1)**

If wrong salt chosen maximum of 2 marks (the comparison of the ions)

And

Br^- has larger ionic radius than Cl^- / Br^- has lower charge density than Cl^- / ora **(1)**;

Not Br has larger radius

K^+ has a lower charge than Ca^{2+} / K^+ has lower charge density than Ca^{2+} / K^+ has a larger ionic radius than Ca^{2+} / ora **(1)**;

Not *K has lower charge*
Not *K^+ has larger atomic radius*

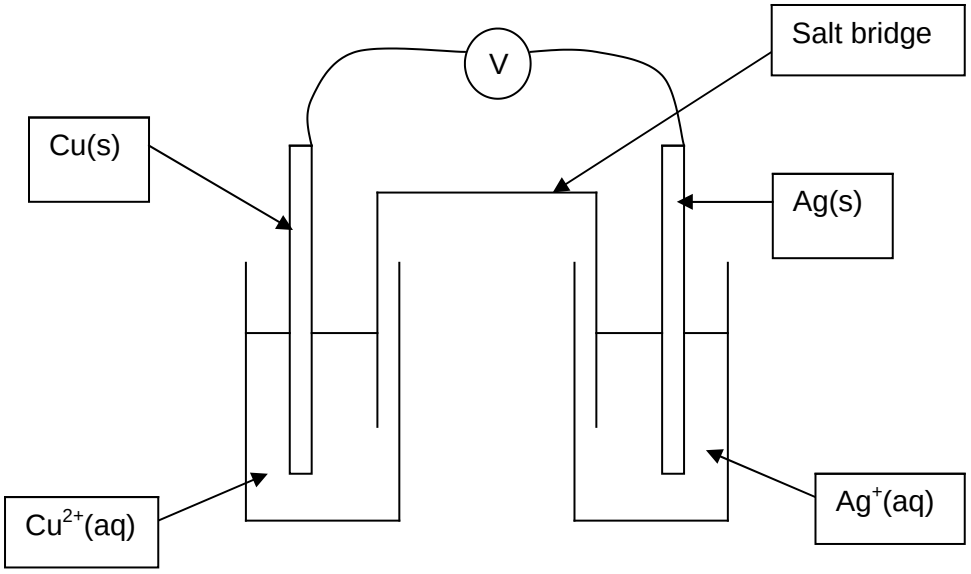
Strongest attraction between ions (when smallest radius and highest charge) / strongest attraction between ions (with the highest charge density) / ora **(1)** 4

Penalise *use of atoms rather than ions just once in this question*

[10]

13. (a) Emf / voltage / potential difference 1
Half cell combined with standard hydrogen electrode 1
Standard conditions 298K, 1 mol dm^{-3}, 1 atm 1
(all 3 required for 1 mark)

(b) (i) Diagram shows:
Voltmeter + salt bridge + complete circuit 1
Solution labelled Cu^{2+} and electrode labelled Ag 1



(ii) Direction from Cu(s) to Ag(s) (must be in / close to wire) 1

(iii) 0.80 – 0.34 = 0.46 V 1

(iv) $Cu + 2Ag^{+} \rightarrow Cu^{2+} + 2Ag$ 1

(c) Standard Electrode Potential for chlorine is more positive than Fe^{3+} therefore it is a better oxidising agent than Fe^{3+} (do not accept $E^{\ominus}$ is larger or smaller) 1
Standard Electrode Potential for iodine is less positive than Fe^{3+} therefore it is a poorer oxidising agent than Fe^{3+} 1
(Accept release of electrons/equilibrium arguments)

[10]

14. $4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ **(1)**

N from +4 to +5
O from 0 to –2 **(1)** Could be below equation 2

[2]

15. (a) (i) Electron affinity -696 (1 mark);
Atomisation of Cl_2 +244 (1 mark);
From top to bottom
2^{nd} IE +1150,
1^{st} IE +590,
atomisation of Ca +178
formation -796 (1 mark) 3

Allow *244, 1150, 590 and 176 i.e. without plus sign*

(ii) -796 - 178 - 590 - 1150 - 244 + 696 **(1)**;

But

-2262 (with no working) (2) 2

Allow *ecf from the wrong figures on the Born-Haber cycle*
1 error ***max one mark***
2 errors ***0 mark***

(iii) Magnesium fluoride more exothermic than calcium chloride / ora

Answer must refer to the correct particle.

because

Ionic radius of Mg^{2+} is less than that of Ca^{2+} / charge density of magnesium ion is greater than that of calcium ion / ora **(1)**;
Ionic radius of F- is less than that of Cl^- / charge density of fluoride ion is greater than that of chloride ion / ora **(1)**;

Not *Mg or magnesium has a smaller radius or fluorine has a smaller radius*

Stronger (electrostatic) attraction between cation and anion in MgF_2 than in $CaCl_2$ / stronger ionic bonds in MgF_2 **(1)** 3

Allow *magnesium or fluorine has a smaller ionic radius*

(b) **Any two from**
For second ionisation energy the electron lost is closer to the nucleus / AW **(1)**;
For second ionisation energy the electron is lost from a particle that is already positive **(1)**;
For second ionisation energy there is one more proton than electron **(1)**
So outer electron more firmly attracted to the nucleus **(1)** 2

Allow *ora*

[10]

16. (a) (i) Oxidation state of nitrogen goes from +5 to +4 **(1)**;
Oxidation state of oxygen goes from –2 to 0 **(1)**;

Correct linking of changes of oxidation state with reduction **and** with oxidation **(1)** 3

*If oxidation state of barium given is incorrect **max 1** for the oxidation numbers.*

***Allow** ecf from wrong oxidation states for the correct linking mark*
***Both** oxidation **and** reduction needed*

(ii) Correct use of molar ratios **(1)**;
Correct cycle **(1)**;
(+)1000 (kJ mol^{-1}) **(1)** 3

***Award** full marks for (+) 1000 (kJ mol^{-1})*
***Only allow** ecf for final lattice energy answer from a correct cycle*
Allow** –1000 **(1)**, +467 **(2)**, +901 **(2)**, +1558 **(2)

(b) (i) Moles of $Ba(NO_3)_2$ = 0.005 or 0.00502 **(1)**;
Moles of gas made = 0.0125 / 0.0126 **(1)**;
Volume of gas = 300 cm^3 to 302 cm^3 **(1)** 3

***Allow** ecf within question*
***Ignore** significant figures*

(ii) Decomposition temperature may be too high / too much gas will be produced / to fill a gas syringe need a smaller amount of solid / gas syringe too small **(1)** 1

***Allow** NO_2 is toxic / barium compounds are toxic*
*Answer is **consequential** on answer to (i)*

[10]

17. (a) Emf of a cell / voltage / potential difference / cell potential 1
Comprising half cell combined with standard hydrogen electrode 1
Conc = 1 $mol.dm^{-3}$; Pressure (of H_2) = 1 atm; Temp = 298K 1
(all of above = 1 mark)

(b) +0.16 V (unit required) 1

[4]

18. (a) (i) $2MnO_4^- + 10Cl^- + 16H^+ \rightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$ 1

correct species on both sides of equation equation balanced (ignore electrons for first mark, penalise for balance) 1

(ii) Chlorine $-1 \rightarrow 0$ 1
Manganese $+7 \rightarrow +2$ 1
Link to (i) and allow ecf

(iii) Chloride ion oxidised (not chlorine) 1
Manganate(VII) ion reduced (not manganese) 1

(d) 0.16 V too small/rate too slow/insufficient activation energy/not standard conditions 1

[7]