1. (a) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$ 1

(b) $S^-(g)$ 1

(c) The negative S^- ion   1
repels the electron being added   1

(d) (i) Enthalpy of atomisation of sulphur   1

   (ii) Second ionisation enthalpy of calcium   1

   (iii) Second electron affinity of sulphur   1

(e) Electron more strongly attracted   1
nearer to the nucleus or attracted by Ca^+ ion   1

(f) Correct cycle

e.g. $+\,178 + 279 + 590 + 1145 - 200 + E - 3013 + 482 = 0$ 1

$= 539$ 1

Allow one mark for -539

[11]

2. (a) ΔH_1 formation **(1)**

ΔH_2 atomisation / sublimation (of Cs <u>not</u> Cl) **(1)**

ΔH_5 electron affinity (of Cl) **(1)**   3

(b) $-433 = 79 + 376 + 121 - 364 + \Delta H_6$ **(1)**

$\Delta H_6 = -645$ (kJ mol^{-1}) **(1)**   2

both marks for correct answer alone
allow 1 mark for +645 or 645

(c) Cs has larger radius / larger atom (not ion) / more shells /
more orbitals / more sub-shells **(1)**

correct reference to shielding **(1)**

less powerful attraction (of nucleus) for (outer) e$^-$ in Cs **(1)**   3

[8]

3. (a) (i) diagram shows in top box $Rb^+(g) + e^- + I(g)$ / e^- must be there **(1)**

diagram shows in lower box $Rb(\underline{s}) + ½ I_2(\underline{s})$ **(1)** 2

(ii) ΔH_1 = electron affinity (of iodine)/allow correct symbols
including I_2, I^-, **(1)**

ΔH_2 = lattice enthalpy / energy (of RbI) **(1)** 2

(iii) $\Delta H_1 = -(+402) - (+107) - (+85.8) + (-328) - (-609)$ **(1)**

$= -314$ (kJ mol^{-1}) **(1)** 2

give 1 mark for +313.8 or +314
assume + if no sign given
significant figure penalty for 310

[6]

4. (i) **A** is (enthalpy change) of formation **(1)**

B is lattice enthalpy **(1)** 2

(ii) negative sign (only if a calculation) **(1)**

883 kJ mol^{-1} **(1)**

(only give both marks if working and answer correct)

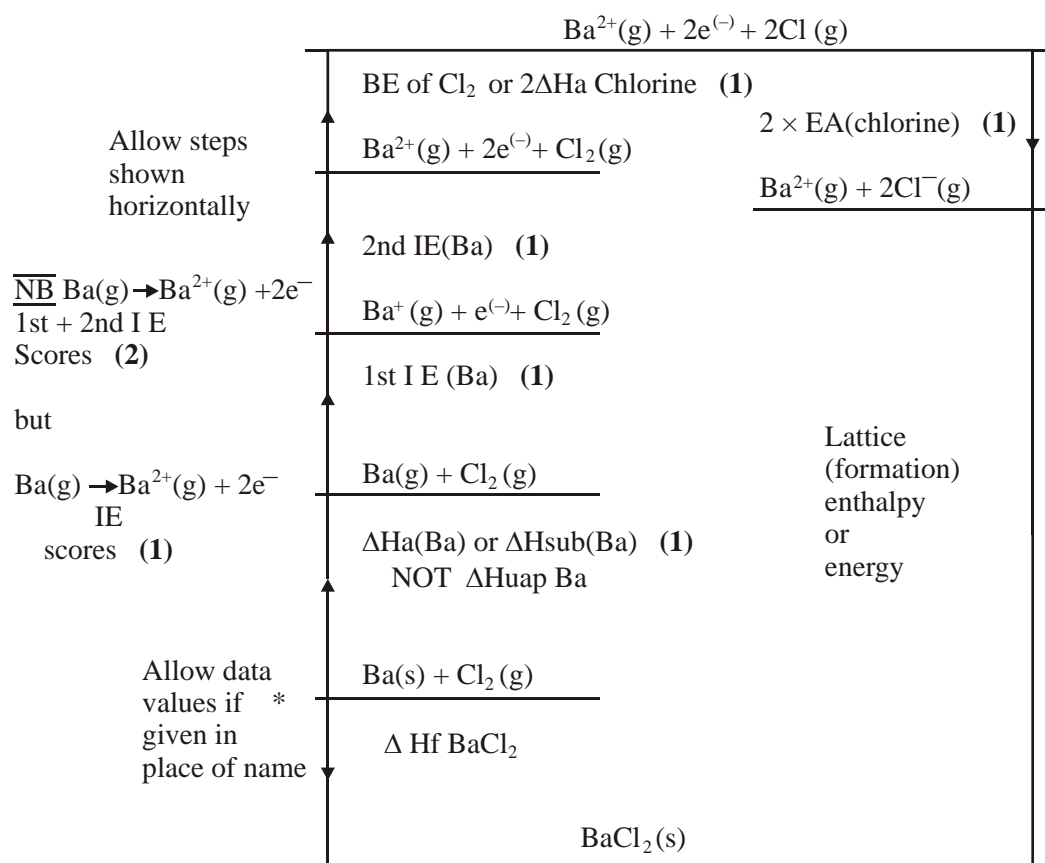hydration / solvation enthalpies (of Li^+ and Cl^-) **(1)** 3

[5]

5. (a) Particles are in maximum state of order 1
*(or perfect order or completely ordered or perfect crystal or
minimum disorder or no disorder)*
(entropy is zero at 0 k by definition)

(b) (Ice) melts 1
(or freezes or changes from solid to liquid or from liquid to solid)

(c) Increase in disorder 1
Bigger (at T_2) 1
Second mark only given if first mark has been awarded

(d) (i) Moles of water = 1.53/18 (= 0.085)   1

Heat change per mole = 3.49/0.085 = 41.1 (kJ mol^{-1})   1
(allow 41 to 41.1, two sig. figs.)

(penalise –41 (negative value), also penalise wrong units but allow kJ only)

(ii) $\Delta G = \Delta H - T\Delta S$ 1

(iii) $\Delta H = T\Delta S$ or $\Delta S = \Delta H/T$ 1
(penalise if contradiction)

$\Delta S = 41.1/373 = 0.110$ kJ K^{-1} (mol^{-1}) (or 110 (J K^{-1} (mol^{-1})))   1
(allow 2 sig. figs.)

(if use value given of 45, answer is 0.12 (or 120 to 121)

(if ∪H is negative in (d) (i), allow negative answer)

(if ∪H is negative in (d) (i), allow positive answer)

(if ∪H is positive in (d) (i), penalise negative answer)

Correct units as above (mol^{-1} not essential)   1

[10]

6. (a) (i)

$$Ba^{2+}(g) + 2e^{(-)} + 2Cl\,(g)$$

BE of Cl_2 or $2\Delta Ha$ Chlorine **(1)**

$2 \times$ EA(chlorine) **(1)**

$$Ba^{2+}(g) + 2e^{(-)} + Cl_2(g)$$

$$Ba^{2+}(g) + 2Cl^-(g)$$

Allow steps shown horizontally

2nd IE(Ba) **(1)**

$\overline{NB}$ $Ba(g) \rightarrow Ba^{2+}(g) + 2e^-$
1st + 2nd I E
Scores **(2)**

$$Ba^+(g) + e^{(-)} + Cl_2(g)$$

but

1st I E (Ba) **(1)**

$Ba(g) \rightarrow Ba^{2+}(g) + 2e^-$
         IE
   scores **(1)**

$$Ba(g) + Cl_2(g)$$

Lattice (formation) enthalpy or energy

$\Delta Ha(Ba)$ or $\Delta Hsub(Ba)$ **(1)**
   NOT $\Delta Huap\ Ba$

Allow data values if   *
given in place of name

$$Ba(s) + Cl_2(g)$$

Δ Hf $BaCl_2$

$$BaCl_2(s)$$

ONLY consider species involved in the step marked

(ii)   Cycling clockwise about (*)
       CE if step missing

$\Delta H_aBa + 1^{st}$ IEBa $+ 2^{nd}$ IE Ba $+ 2\Delta H_aCl + 2EACl + LE - \Delta H_fBaCl_2 = 0$ **(1)**
$+180 + 503 + 965 + 2 \times 122 + 2EA - 2056 + 859 = 0$ **(1)**
EA $= -695/2 = -$ (347 to 348) **(1)**   9
     Ignore units

     Calculation –1 for each error

     Mark conseq.

     Notes: –695 scores (2)
             +(347 to 348) scores (2)
             –(286 to 287) scores (2)
             +(286 to 287) scores (1)
             –573 scores (1)
             +573 scores (0)

(b) $\Delta S = \Sigma S$ products $- \Sigma S$ reactants
         $= (63 + 223) - 124 = 162$ **(1)**

     $\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ or $T = \Delta H/\Delta S$ **(1)**
              or used correctly

     $\Delta H = 859 \times 10^3$ **(1)** $= T \times 162$
     $T = (5\,300$ to $5304)$ K **(1)**   4
              Penalise if units °C

              –1 for each error + mark conseq.

                                                                   [13]

7.   (a)   (i)   *Standard enthalpy change*: $\Delta H_R = \Sigma\Delta H_f$ products $- \Sigma\Delta H_f$
                  reactants **(1)**
                  $\Delta H_R = (-804 - 394) - (-940)$ **(1) N.B: If answer wrong**
                  statement worth 2
                    $= -258$ (kJ mol^{-1}; ignore units completely) **(1)**
                  Allow +258 (2) marks

                  Standard entropy change: $\Sigma\Delta S$ products $- \Sigma\Delta S$ reactants **(1)**
                  $\Delta S = (252 + 214) - (49.9 + 5.7 + [2 \times 223])$ **(1) N.B: If answer**
                  wrong statement worth 2
                    $= -35.6$ (kJ mol^{-1}; ignore units completely) **(1)**
                  Allow +35.6 (2) marks
                  Mark –36 AE minus one
                  Allow max one for +187

         (ii) $T = \dfrac{H}{S}$ **or** $T = \dfrac{H \text{ value from above}}{S \text{ value from above}}$ **(1)**
               Penalise wrong sign

               $T = \dfrac{-258 \times 1000}{-35.6} = 7245$ to 7250 **(1)**
              Ignore letter after value
              Ignore Í even if wrong way around
              Mark answer conseq to UH and US values from above
              If negative temperature given max 2*
              If °C used incorrectly max 2*
              * But only penalise one of these errors

                                                   9
                                                       [9]

8. (a) (i) *Standard enthalpy change*: $\Delta H_R = \Delta\Sigma\, H_f(\text{products}) - \Delta\Sigma\, H_f(\text{reactants})$ **(1)**
or cycle

$\Delta H_R = ([2 \times 0] + [3 \times -393.5]) - (-824.2 + [3 \times -110.5])$ **(1)**
$\quad = -24.8 \text{ (kJ mol}^{-1})$ **(1)**
Allow + 24.8 max one

Standard entropy change: $\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$ **(1)**

$\Delta S = ([2 \times 27.3] + [3 \times 213.6]) - (87.4 + [3 \times 197.6])$ **(1)**
$\quad = (54.6 + 640.8) - (87.4 + 592.8)$ **(1)**
$\quad = 15.2 \text{ (JK}^{-1}\text{mol}^{-1})$ **(1)**
Allow -15.2 max one

(ii) $\Delta G = \Delta H - T\Delta S$ **(1)**
ΔH negative and $-T\Delta S$ is negative **(or ∪S positive or or correct calc) (1)**
Hence ΔG is always negative **(or feasible when ∪G ½ 0) (1)**   9

(b) $\Delta G = 0 = \Delta H - T\Delta S$ Hence $\Delta H = T\Delta S$ **(1)**
$T = \Delta H / \Delta S = 492.7 \times 1000 / 542.6$ **(1)**
$\quad = 908 \text{ K}$ **(1)**
penalise missing 1000 by one mark

3

(c) $\Delta G \text{ (b)} = \Delta G \text{ (a)}$
$(492.7 \times 10^3 - T \times 542.6) = (-24.8 \times 10^3 - T \times 15.2)$ **(1)**
$517.5 \times 10^3 = 527.4 \text{ T}$ **(1)**
$T = 981.2 \text{ K}$ **(1)**
Allow 980 - 982
Penalise missing 1000 by one mark

3

[15]

9. (a) $\Delta H_a = \Sigma\, \Delta H_f \text{ products} - \Sigma\, \Delta H_f \text{ reactants or}$

$= \Delta H_f\, CO_2 - (\Delta H_f\, CH_4 + 2\,\Delta H_f\, H_2O)$ **(1)**

$= -393.5 + (74.8 + [2 \times 241.8])$ **(1)**

$= +164.9 \text{ kJ mol}^{-1}$ **(1)**   3

(b) (i) The number of moles of gas increases from 3 to 5 **(1)**

More moles gas gives more disorder **(1)**

(ii) $\Delta S = \Sigma S \text{ prducts} - \Sigma S \text{ reactants}$ **(1)**

$= (213.6 + [4 \times 130.6]) - (186.2 + [2 \times 188.7])$ **(1)**

$= +172.4 \text{ JK}^{-1} \text{ mol}^{-1}$ **(1)**   5

(c) (i) $\Delta G = \Delta H - T\Delta S$ or $\Delta H = T\Delta S$ **(1)**

$T = 164.9 \times 1000/172.4$ **(1)**

$= 956.5$ K **(1)**

Marked consequentially

(ii) Above this temperature **(1)**

this reaction is feasible or spontaneous **(1)**   5

[13]

10. (a) $\mathsf{U}H^{\ominus}$ $\Delta H^{\ominus} = \Sigma \Delta H_{\mathbf{f}}^{\ominus}$ (products) $- \Sigma \Delta H_{\mathbf{f}}^{\ominus}$ (reactants) **(1)**

$= -201 + 110$

$= -91$ kJmol^{-1} **(1)**

$\mathsf{U}S^{\ominus}$ $\Delta S^{\ominus} = \Sigma S^{\ominus}$ (products) $- \Sigma S^{\ominus}$ (reactants) **(1)**

$= +240 - 2 \times 131 - 198$

$= -220$ JK^{-1} mol^{-1} **(1)**   4

(b) *Feasible reaction*   One for which $\Delta G \leq O$ **(1)**

Temperature $\Delta G = \Delta H - T\Delta S$ **(1)**

For $\Delta G = O$, $T = \Delta H/\Delta S = -91 \times 1000/(-220)$

$= 414$ K **(1)**   3

[7]

11. (a) $\Delta H^{\ominus} = \Sigma \Delta H_{\mathbf{f}}^{\ominus}$ (products) $- \Sigma \Delta H_{\mathbf{f}}^{\ominus}$ (reactants) **(1)**

$= 2 \times (-396) - 2 \times (-297)$

$= -198$ kJ mol^{-1} **(1)**

$\Delta S^{\ominus} = \Sigma S^{\ominus}$ (products) $- \Sigma S^{\ominus}$ (reactants) **(1)**

$= 2 \times (257) - 204 - 2 \times (248)$

$= -186$ JK^{-1} mol^{-1} **(1)**

$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ **(1)**

$= -198 - 298 (-186/1000)$ **(1)**

$= -143$ kJ mol^{-1} **(1)**   7

(b) One for which $\Delta G \leq O$ **(1)**

$T = \dfrac{\Delta H}{\Delta S}$ when $\Delta G = O$ **(1)**

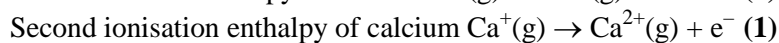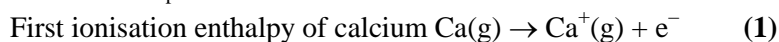$= \dfrac{-198 \times 1000}{-186} = 1100$K **(1)**   3

[10]

12. (i)   fewer moles of gas **(1)**

more 'order' in system **(1)**
dependent on idea of fewer moles for first mark   2

(ii)   25 °C = 298 K **(1)**

$$\Delta S = \frac{-188}{1000} \textbf{ or } (\Delta H \times 1000) \textbf{ (1)}$$

mark is for ensuring ΔH or ΔS are both expressed in terms of J or kJ

$\Delta G = -196 - 298(-188 \times 10^{-3})$
          $= -140$ kJ mol^{-1} **or** -139976 J mol^{-1} **(1)**

ignore sig. figs
sign and unit must be correct in final answer

ΔG –ve $\therefore$ reaction feasible **(1)**   4

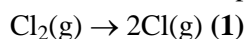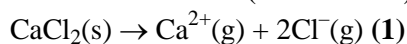   **[6]**

**13.** (a) (i) <u>Steps</u>

Sublimation/atomisation enthalpy or
$\Delta H_{fus} + \Delta H_{vap}$ $Ca(s) \rightarrow Ca(g)$ **(1)**

First ionisation enthalpy of calcium $Ca(g) \rightarrow Ca^+(g) + e^-$ **(1)**

Second ionisation enthalpy of calcium $Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ **(1)**

Dissociation enthalpy/bond energy/$2 \times \Delta H_a$ chlorine
$Cl_2(g) \rightarrow 2Cl(g)$ **(1)**

$2 \times$ First electron affinity of chlorine $2Cl(g) + 2e^- \rightarrow 2Cl^-(g)$ **(1)**

Lattice dissociation (or formation) enthalpy
$CaCl_2(s) \rightarrow Ca^{2+}(g) + 2Cl^-(g)$ **(1)**

Enthalpy of formation of calcium chloride
$Ca(s) + Cl_2(g) \rightarrow CaCl_2(g)$ **(1)**
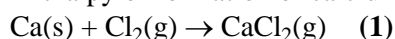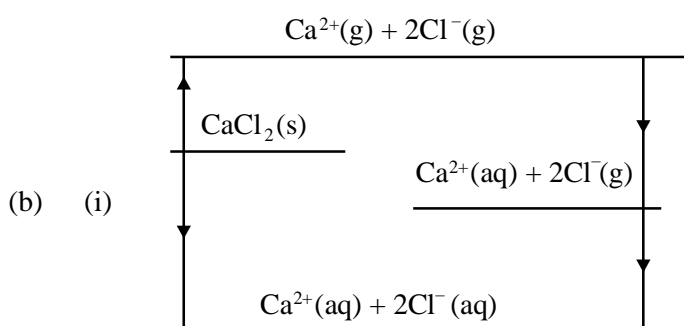
7

(ii) 2nd IE needed when $CaCl_2$ formed or only 1st IE for CaCl **(1)**

BE of Cl_2 needed when $CaCl_2$ formed but BE/2 for CaCl
(or equivalent) **(1)**

$2 \times$ electron affinity when CaCl2 formed but $1 \times$ EA for CaCl **(1)**

LE of $CaCl_2$ greater (or different) than LE CaCl **(1)**   4

$$Ca^{2+}(g) + 2Cl^-(g)$$

$CaCl_2(s)$

$Ca^{2+}(aq) + 2Cl^-(g)$

(b) (i)

$Ca^{2+}(aq) + 2Cl^-(aq)$

$+LE + (\Delta H_{hyd}Ca^{2+}) + 2(\Delta H_{hyd}Cl^-) - \Delta H_{soln}$ $CaCl_2 = CaCl_2 = 0$ or correct cycle **(1)**

ΔH_{soln} CaCl2 $= 2255 - 1650 - 768$ **(1)**

$= -163$ kJ mol^{-1} **(1)**   3

(ii) Marked consequentially to answer in (c)(i)
Solubility decreases **(1)**
Enthalpy of solution negative or exothermic **(1)**
Equilibrium displaced as predicted by Le Chatelier **(1)**   3

(c) (i) $\Delta H_c^{\ominus}$ $(CH_2)_4 = 4\Delta H_f^{\ominus}$ $CO_2 + 4\Delta H_f^{\ominus}$ $H_2O - \Delta H_f^{\ominus}$ $(CH_2)_4$ **(1)**

$-2558 = (4 \times -393.5) + (4 \times -245.1) - \Delta H_f^{\ominus}$ $(CH_2)_4$ **(1)**

$\Delta H_f^{\ominus}$ $(CH_2)4 = +3.6$ kJ mol^{-1} **(1)**   3

(ii) Enthalpy put in to break bonds

$4 \times C - C = 4 \times 347$ **(1)** $= 1388$
$8 \times C - H = 8 \times 413$ **(1)** $= 3304$
$6 \times O = O = 6 \times 498$ **(1)** $= 2988$

Total   = 7680

Enthalpy given out when bonds made

$8 \times C = O = 8 \times -805$ **(1)** $= -6440$
$8 \times O - H = 8 \times -464$ **(1)** $= -3712$

Total   = -10152

Enthalpy change = Enthalpy in – enthalpy out
$= 7680 - 10152$ **(1)**
$= -2472$ kJ mol^{-1} **(1)**

marked consequentially

<u>Explanation</u>

Mean bond enthalpies used or bond enthalpies depend on environment **(1)**
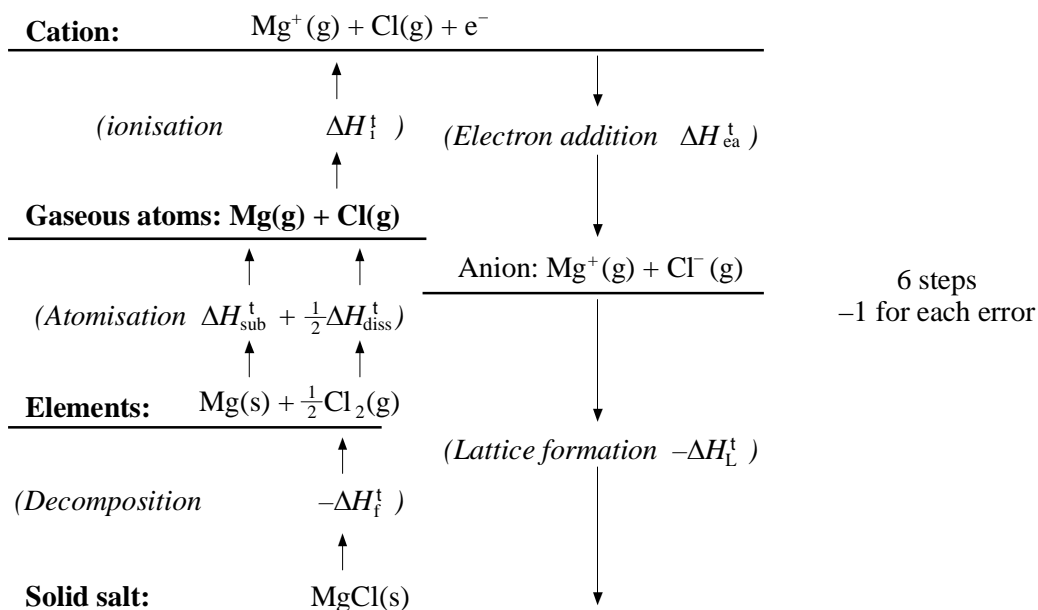
Cyclobutane less stable than suggested by mean bond enthalpies **(1)**

Cyclobutane a strained structure or bond angles 90° **(1)**   10

Stability of cyclobutane marked consequentially.

[30]

14

Cation: $Mg^+(g) + Cl(g) + e^-$

(ionisation ΔH_i^{t} *)* *(Electron addition* ΔH_{ea}^{t} *)*

Gaseous atoms: Mg(g) + Cl(g)

(Atomisation $\Delta H_{sub}^{t} + \frac{1}{2}\Delta H_{diss}^{t}$ *)*

Anion: $Mg^+(g) + Cl^-(g)$

6 steps
–1 for each error

Elements: $Mg(s) + \frac{1}{2}Cl_2(g)$

(Decomposition $-\Delta H_f^{t}$ *)* *(Lattice formation* $-\Delta H_L^{t}$ *)*

Solid salt: $MgCl(s)$

4

$$0 = -\Delta H_f^{\ominus} + \Delta H_{sub}^{\ominus} + \Delta H_{diss}^{\ominus} + \Delta H_f^{\ominus} + \Delta H_{ea}^{\ominus} + \Delta H_f^{\ominus}$$

$$\Delta H_f^{\ominus} = \Delta H_{sub}^{\ominus} + \Delta H_{diss}^{\ominus} + \Delta H_f^{\ominus} + \Delta H_{ea}^{\ominus} + \Delta H$$

$$\Delta H_f^{\ominus} = +146 + 121 + 736 - 364 - 753$$

$$\Delta H_f^{\ominus} = -114 \text{ kJ mol}^{-1} \textbf{ (3)} \qquad [-1 \text{ for each error}] \qquad 2$$

$\Delta H^{\ominus} = \Delta H_f^{\ominus}$ $(MgCl_2) - \Delta H_f^{\ominus}$ $(MgCl) = -653 - 2(-114) = -425$ kJ mol^{-1} 1

$\Delta S^{\ominus} \approx 0$ since 2 mol solid $\rightarrow$ 2 mol solid 1

if $\Delta S^{\ominus} = 0$, then $\Delta G^{\ominus} = \Delta H^{\ominus}$ 1

So $\Delta G^{\ominus}$ for the reaction is < 0 (at all *T*)– hence MgCl$_2$ is always favoured over MgCl 1

[10]

15 (a) Heat (energy)/ internal energy change (not energy change) **(1)**
Measured at <u>constant pressure</u> **(1)**   2

(b)

$$Mg^{2+}(g) + O^{2-}(g)$$
2nd EA O

$$Mg^{2+}(g) + 2e^- + O(g)$$
(1st) EA O

$$Mg^{2+}(g) + e^- + O^-(g)$$

$\Delta H_a O$

$$Mg^{2+}(g) + 2e^- + \frac{1}{2}O_2(g)$$
2nd IE (Mg)

$$Mg^+(g) + e^- + \frac{1}{2}O_2(g)$$
1st IE (Mg)

$$Mg(g) + \frac{1}{2}O_2(g)$$
ΔH_a (Mg) or ΔH_{sub}

$$Mg(s) + \frac{1}{2}O_2(g)$$

ΔH_f MgO

MgO(s)

LE Form MgO
or – LE dissociation
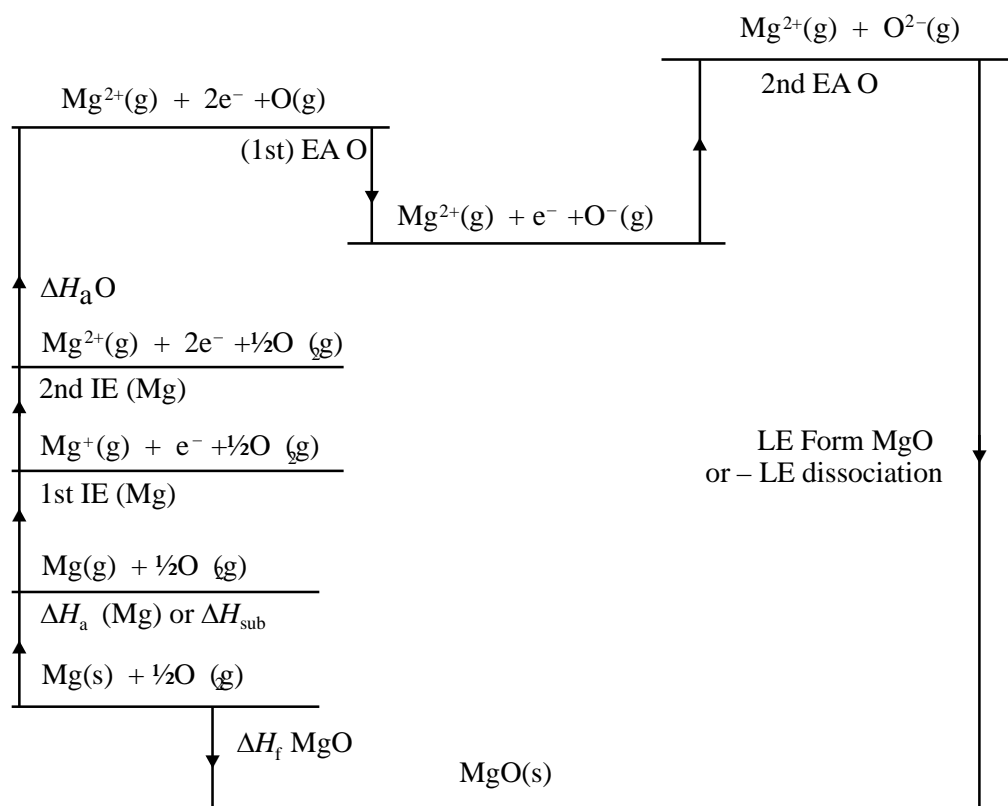
8

Notes:– Ignore electrons in cycle

Penalise missing labels by max 2

Penalise missing state symbols in 'active step' by max 2

Penalise incorrect chemistry every time

Allow steps written horizontally

Calculation:

$\Delta H_a Mg + 1^{st} IE\ Mg + 2^{nd} IE\ Mg + \Delta H_a\ O + 1^{st}\ EA\ O + 2^{nd}\ EA\ O + LE\ Form - MgO\ \Delta H_f MgO = 0$ **(1)**

Hence; $148 + 738 + 1451 + 249 - 141 + 798 + LE + 602 = 0$ **(1)**

(NB This scores 2)

LE formation MgO $= -3845$ (kJ mol^{-1}) **(1)**

(Allow +3845 Max 2)

(c) For the reaction $MgCl_2(s) + \frac{1}{2}Cl_2(g) \rightarrow MgCl_3(s)$

ΔH_r = $\Delta H_f MgCl_3 - \Delta H_f MgCl_2$

      = +3904 – (–653) = 4557 (kJ mol^{-1}) **(1)**

ΔS is negative/ entropy decreases (as order increases) **(1)**

$\Delta G = \Delta H - T\Delta S$ **(1)**

ΔG must (always) be positive (since ΔH_r and $-T\Delta S$ are both positive) **(1)**

Reaction never/not feasible (or equivalent) **(1)**

    5

    [15]

16. $\Delta S = \Sigma S$ products $- \Sigma S$ reactants   1

        $\Delta S = (259 + 187) - (201 + 161)$ 1

        $\Delta S = 84$ (JK^{-1} mol^{-1}) *(Ignore units)*   1
            Allow – 84 to score **(1)** *mark*

        $\Delta G = \Delta H - T\Delta S$ 1

          $= -21.6 - 298 \times 84/1000$
          $= -46.6$ kJ mol^{-1} or $-46\,600$ J mol^{-1} 1
          Allow **(2)** *for – 46.6 without units*
          (Mark ΔG consequentially to incorrect ΔS)
          (e.g. $\Delta S = -84$ gives $\Delta G = +3.4$ kJ mol^{-1})

     1

    [6]

17. (a)   Reaction 1

$\Delta H = \Sigma\Delta H_f$ products $-\Sigma\Delta H_f$ reactants **(1)**

$= (\Delta H_f CO) - (\Delta H_f CH_4 + \Delta H_f H_2O)$

$= (-110.5) - (-74.8 - 241.8) = +206.1$ (kJ mol^{-1}) **(1)**

$\Delta S = \Sigma S$ products $-\Sigma S$ reactants **(1)**

$= (197.6 + [3 \times 130.6]) - (186.2 + 188.7) = 214.5$ (J K^{-1}mol^{-1}) **(1)**

$\Delta G = \Delta H - T\Delta S$ **(1)**

$0 = + 206.1 - T \times 214.5/1000$ **(1)**

$T = 206.1 \times 1000/214.5 = 960.8$ (K) **(1)**

(allow 961)

Penalise incorrect units in calculation of temperature by 2 marks

Mark T consequentially

Reaction 2

$\Delta H = 2\Delta H_f NH_3 = -92.2$ (kJ mol^{-1}) **(1)**

$\Delta S = (2 \times 192.3) - (191.6 + [3 \times 130.6]) = -198.8$ (J K^{-1}mol^{-1}) **(1)**

$\Delta G = 0 = -92.2 + T \times 198.8/1000$

$T = 92.2 \times 1000/198.8 = 463.8$ (k) **(1)**

(allow 464)

Mark T consequentially

Note:– Allow first calculation max 7 and second calculation max 3   10

(b)   <u>Reaction 1 at higher temperatures</u>

equilibrium yield increased/forward reaction favoured as reaction
endothermic **(1)**

rate of reaction increased **(1)**

a compromise temperature used based on high cost of high
temperature **(1)**

<u>Reaction 2 at higher temperatures</u>

equilibrium yield reduced/backward reaction favoured as reaction
exothermic **(1)**

rate of reaction increased **(1)**

a compromise temperature used based on overall yield **(1)**

Mark consequentially to ∪H values in (a)   max 5

[15]

18. (a)   Spontaneous when $\Delta G < 0$ or $\Delta G = 0$ **(1)**

$\Delta G = \Delta H - T\Delta S$ **(1)**

Calculation of ΔH; $\Delta H_{\text{reaction}} = \Sigma \Delta H_{\text{Prolucts}} - \Sigma \Delta H_{\text{Reactants}}$ **(1)**

   $= (2 \times -110.5) - (-3935) = + 172.5$ Allow $172 - 173$ kJ mol^{-1} **(1)**

Calculation of ΔS; $\Delta S_{\text{reaction}} = \Sigma \Delta S_{\text{Products}} - \Sigma S_{\text{Reactants}}$ **(1)**

   $= (2 \times 197.6) - (5.7 + 213.6) = 175.9$ J mol^{-1} K^{-1} **(1)**

Calculation of T $\Delta G = 172.5 - T \times 175.9/1000 = 0$ **(1)**

$T \times 175.9/1000 = 172.5$

$T = 172.5 \times 1000/175.9 = 980.7$ K **(1)**   8

(b)   Calculation of $\Delta H_{\text{Vaporisation}}$;
   3675 J vaporise 1.50 g water
   $3675 \times 18/1.50$ vaporise 1.00 mole water
   $= 44.1$ kJ mol^{-1} **(1)**

Calculation of ΔS; $\Delta G = 0 = 44.1 - 373 \times \Delta S/1000$ or $\Delta S = \Delta H/T$ **(1)**
   $\Delta S = 44.1 \times 1000/373 = 118.2$ J mol^{-1} K^{-1} **(1)**   3

                                                                                    [11]

19. (a) $\Delta H_f^{\ominus} = \Sigma\Delta H_f^{\ominus}$ (products) $- \Delta H_f^{\ominus}$ (reactants) **(1)**

   $= (-110.5) - (-271.9) = +161.4$ [Allow $161 - 161.5$] kJ mol^{-1} **(1)**

$\Delta S^{\ominus} = \Sigma S^{\ominus}$(products) $- \Sigma S^{\ominus}$(reactants) **(1)**

$= (27.3 + 197.6) - (58.5 + 5.7) = +160.7$
[Allow $160.6 - 161$] J mol^{-1} K^{-1}**(1)**

$\Delta G = \Delta H - T\Delta S$ [Stated or correctly used] **(1)**

$\Delta G = +161.4 - 450 \times 160.7/1000$ **(1)**

   $= +89.1$[Allow $88.5 - 89.1$] kJ mol^{-1}. **(1)**

$\Delta H_f^{\ominus} = (-393.5) - (-271.9 - 110.5) = -11.1$ kJ mol^{-1}. **(1)**

$\Delta S^{\ominus} = (213.6 + 27.3) - (58.5 + 197.6) = -15.2$ J mo1^{-1} K^{-1}. **(1)**

$\Delta G = -11.1 + 450 \times 15.2/1000 = -4.26$ [Allow-4.3] kJ mol^{-1}. **(1)**   10

(b)   Feasible when $\Delta G \leq 0$ or ΔG is negative **(1)**

Process 1 is more feasible as temperature is increased **(1)**

Because ΔS is positive or $-T\Delta S$ is negative or $T\Delta S$ is positive **(1)**

Process 2 is less feasible as temperature is increased **(1)**

Because ΔS is negative or $-T\Delta S$ is positive or $T\Delta S$ is negative **(1)**   5

[15]