## Born-Haber Cycles

## Mark Scheme 7

| Level | International A Level |
| :--- | :--- |
| Subject | Chemistry |
| Exam Board | CIE |
| Topic | Chemical Energetics |
| Sub-Topic | Born-Haber Cycles |
| Paper Type | Theory |
| Booklet | Mark Scheme 7 |


| Time Allowed: | 64 minutes |  |
| :--- | :--- | :--- |
| Score: | $/ 53$ |  |
| Percentage: | $/ 100$ |  |
|  |  |  |

Grade Boundaries:

| A* | A | B | C | D | E | U |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| $>85 \%$ | $777.5 \%$ | $70 \%$ | $62.5 \%$ | $57.5 \%$ | $45 \%$ | $<45 \%$ |

$1 \quad$ (a $\mathrm{Ca}^{2+}(\mathrm{g})+2 \mathrm{Cl}^{-}(\mathrm{g}) \longrightarrow \mathrm{CaCl}_{2}(\mathrm{~s})$
(b) $\mathrm{CaF}_{2}$ and CaS both have larger lattice energies (than $\mathrm{CaCl}_{2}$ ) [1
(i) $\mathrm{F}^{-}$is smaller than $\mathrm{Cl}^{-}$
(ii) $\mathrm{S}^{2-}$ is more highly charged than $\mathrm{Cl}^{-}$
(c) LE $=-[178+590+1150]-[244-2 \times 349]-796$ $=-2260\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$
signs $\checkmark$
(d) $\quad \mathrm{Ca}=28.2 / 40.1 \quad=0.703 \quad \Rightarrow 1$
$C=25.2 / 12 \quad=2.10 \quad \Rightarrow 3$
$\mathrm{H}=1.4 / 1 \quad=1.4 \quad \Rightarrow 2 \quad$ (1 mark for initial step of calc'n)
$O=45.1 / 16 \quad=2.82 \quad \Rightarrow 4$
formula is $\mathrm{CaC}_{3} \mathrm{H}_{2} \mathrm{O}_{4}$
(ii) malonic acid must be $\mathrm{C}_{2} \mathrm{H}_{4} \mathrm{O}_{4}$, i.e. $\mathrm{CH}_{3}\left(\mathrm{CO}_{2} \mathrm{H}\right)_{2}$ (must be structural)

2 (a (i) A is $\mathrm{Cl}_{2} /$ chlorine
B is NaCl or HCl or $\mathrm{Cl}^{-}$[or words], etc.
C is salt bridge or $\mathrm{KC} / / \mathrm{KNO}_{3}$, etc.
D is platinum/Pt
E is $\mathrm{Fe}^{2+}+\mathrm{Fe}^{3+}$ or mixture of $\mathrm{Fe}(\mathrm{II})+\mathrm{Fe}$ (III) salts
mention of standard conditions ([ $\left.\mathrm{Cl} l^{-}\right]$of $1 \mathrm{~mol} \mathrm{dm}^{-3}$ or $\mathrm{Cl}_{2}$ at 1 atmos or $\mathrm{T}=25^{\circ} \mathrm{C} / 298 \mathrm{~K}$ )
(ii) $\mathrm{E}^{\ominus}=\mathrm{E}_{\mathrm{R}}^{\ominus}-\mathrm{E}_{\mathrm{L}}^{\ominus}=0.77-1.36=(-) \mathbf{0 . 5 9}(\mathrm{V})$ (ignore sign)
(since R.H. electrode is negative) electrons flow (from right) to left or to the chlorine electrode or anticlockwise or from (beaker) E to (beaker) B
(b) $\quad \Delta \mathrm{H}=3 \times(-167.2)+(-48.5)-(-399.5)$

$$
=-150.6 \text { or } 151\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)
$$

(correct ans [2])
(ii) $2 \mathrm{Fe}^{3+}+\mathrm{Cu} \longrightarrow 2 \mathrm{Fe}^{2+}+\mathrm{Cu}^{2+}$
(or molecular: $2 \mathrm{FeCl}_{3}+\mathrm{Cu} \longrightarrow 2 \mathrm{FeCl}_{2}+\mathrm{CuCl}_{2}$ )
$\mathrm{E}^{\ominus}=0.77-0.34=(+) \mathbf{0 . 4 3}(\mathrm{V})$
(no mark for -0.43 V )
(a)

salt bridge + voltmeter
zinc metal $+\mathrm{Zn}^{2+}$
$\mathrm{H}_{2}$ (in, not out) $+\mathrm{H}^{+}$
Pt electrode
(b)

| conditions | product at anode | product at cathode |
| :--- | :---: | :---: |
| $\mathrm{ZnCl}_{2}($ I) | (chlorine) | zinc [1] |
| $\mathrm{ZnCl}_{2}$ (conc aq) | chlorine [1] | $\left(\mathrm{H}_{2}\right.$ or zinc) (ignore) |
| $\mathrm{ZnCl} l_{2}$ (dil aq) | oxygen [1] | hydrogen [1] |

[1] for each product in correct place [
(c)


LE $=B-A$

$$
=-415-(131+908+1730)-\{244+2(-349)\}
$$

$$
\begin{aligned}
& =-415-2315 \\
& =-2730\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)
\end{aligned}
$$

(correct answer $=[3]$ : deduct [1] for each error) [3]
(d) (i)

- instrumental method (e.g. spectrophotometer/colorimeter/conductance meter)
- what is measured (e.g. absorbance/transmission at a stated wavelength or by use of a "suitable" (green) filter or conductance/resistance)
- measurement of time
- relation of time to rate (e.g. gradient of absorbance/time graph, or rate $\propto 1 / \mathrm{t}$ )
- repeat with different $\left[\mathrm{Zn}^{2+}\right]$, (but the same $[P A R]$ )
- relation of rate to $\left[\mathrm{Zn}^{2+}\right]$ (either by a plot or by simple proportion)
(all 6 points are unconditional on each other) any 5 points [5]
(ii) e.g. add $\mathrm{Br}_{2}(\mathrm{aq})$
decolourises or produces a white ppt.
or add $\mathrm{FeCl}_{3}($ aq or "neutral"); purple colour produced
(a)



15
$2 s$
spherical (1)

$2 p r$
double lobes along the $x$-axis (1)
(b) (i) attraction between bonding electrons and nuclei
attraction is electrostatic
(ii) $\mathrm{H}_{2}$ s-s overlap clearly shown
must not be normal dot/cross diagram
HCl s-p overlap clearly shown
overlap must involve s and p orbitals
(1)
(c) (i) bonding electrons are unequally shared or
the molecule has a dipole/ $\delta+$ and $\delta$ - ends to molecule
(ii) the H and Cl atoms have different electronegativities or chlorine is more electronegative than hydrogen
(d)

allow two 'sausages' above and below the C-C axis
or two p orbitals overlapping sideways to form one (localised) $\pi$ bond over two carbon atoms
penalise errors: no 2 for -393.7
no 2 for -285.9 wrong sign for $-(-1411)$

