Born-Haber Cycles

Question Paper 7

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Question Paper 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 Calcium chloride, $CaCl_2$, is an important industrial chemical used in refrigeration plants, for de-icing roads and for giving greater strength to concrete.

(a) Show by means of an equation what is meant by the lattice energy of calcium chloride.

..... [1]

(b) Suggest, with an explanation, how the lattice energies of the following salts might compare in magnitude with that of calcium chloride.

(i) calcium fluoride, CaF_2

.....

.....

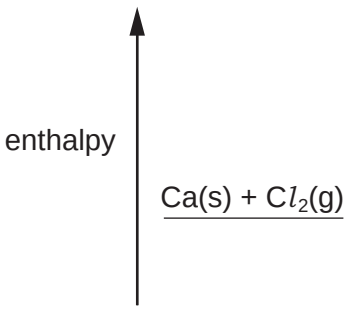
(ii) calcium sulfide, CaS

.....

.....
[3]

(c) Use the following data, together with additional data from the *Data Booklet*, to calculate the lattice energy of $CaCl_2$.

standard enthalpy change of formation of $CaCl_2$	–796 kJ mol^{-1}
standard enthalpy change of atomisation of Ca(s)	+178 kJ mol^{-1}
electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}



lattice energy = ... kJ mol^{-1} [3]

(d) When a solution of $CaCl_2$ is added to a solution of the dicarboxylic acid, malonic acid, the salt calcium malonate is precipitated as a white solid. The solid has the following composition by mass: Ca, 28.2%; C, 25.2%; H, 1.4%; O, 45.2%.

(i) Calculate the empirical formula of calcium malonate from these data.

(ii) Suggest the structural formula of malonic acid.

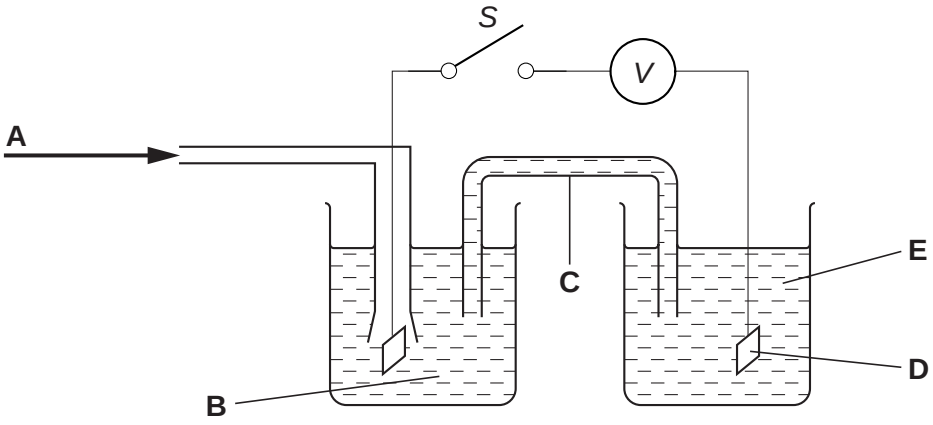
[3]

[Total: 10]

2 Chlorine gas and iron(II) ions react together in aqueous solution as follows.

$$Cl_2 + 2Fe^{2+} \rightarrow 2Cl^- + 2Fe^{3+}$$

(a) The following diagram shows the apparatus needed to measure the $E^{\ominus}_{cell}$ for the above reaction.



(i) In the spaces below, identify what the five letters **A** – **E** in the above diagram represent.

A .....

B .....

C .....

D .....

E .....

(ii) Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction, and hence decide which direction (left to right, or right to left) electrons would flow through the voltmeter *V* when switch *S* is closed.

$E^{\ominus}_{cell}$ = ... V

direction of electron flow .....

[7]

(b) Iron(III) chloride readily dissolves in water.

$$FeCl_3(s) \rightarrow Fe^{3+}(aq) + 3Cl^-(aq)$$

(i) Use the following data to calculate the standard enthalpy change for this process.

species	$\Delta H_f^\ominus$ / kJ mol^{-1}
$FeCl_3(s)$	–399.5
$Fe^{3+}(aq)$	–48.5
$Cl^-(aq)$	–167.2

$\Delta H^\ominus$ = ...kJ mol^{-1}

(ii) A solution of iron(III) chloride is used to dissolve unwanted copper from printed circuit boards.

When a copper-coated printed circuit board is immersed in $FeCl_3(aq)$, the solution turns pale blue.

Suggest an equation for the reaction between copper and iron(III) chloride and use the Data Booklet to calculate the $E^\ominus$ for the reaction.

equation .....

$E^\ominus$ = ... V

[4]

[Total: 11]

3 Zinc chloride is one of the most important compounds of zinc. It is used in dry cell batteries, as a flux for soldering and tinning, as a corrosion inhibitor in cooling towers and in the manufacture of rayon.

(a) Draw a **fully labelled** diagram to show how you could use a standard hydrogen electrode to measure the standard electrode potential, $E^{\ominus}$, of zinc.

[6]

(b) The electrolysis of zinc chloride can give different electrode products, depending on the conditions used.
Suggest the products formed at each electrode in the following cases. One space has been filled in for you.

conditions	product at anode	product at cathode
$ZnCl_2$(l)	***chlorine***	
$ZnCl_2$(concentrated aqueous)		
$ZnCl_2$(dilute aqueous)		

[3]

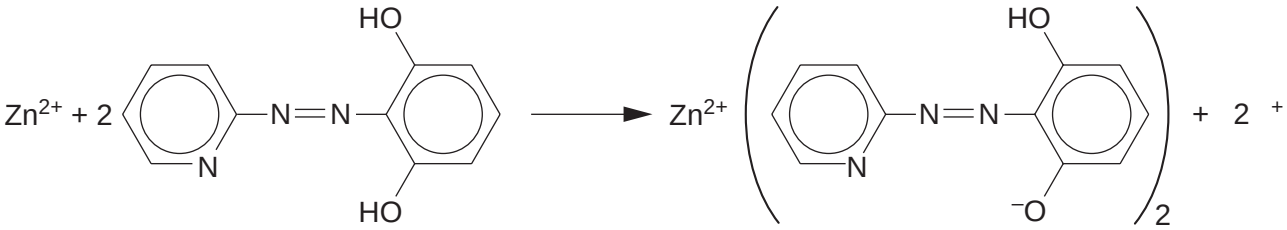
(c) Use the following data, together with relevant data from the *Data Booklet*, to construct a Born-Haber cycle and calculate a value for the lattice energy of zinc chloride.

standard enthalpy change of formation of $ZnCl_2$	–415 kJ mol^{-1}
standard enthalpy change of atomisation of Zn(s)	+131 kJ mol^{-1}
electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}

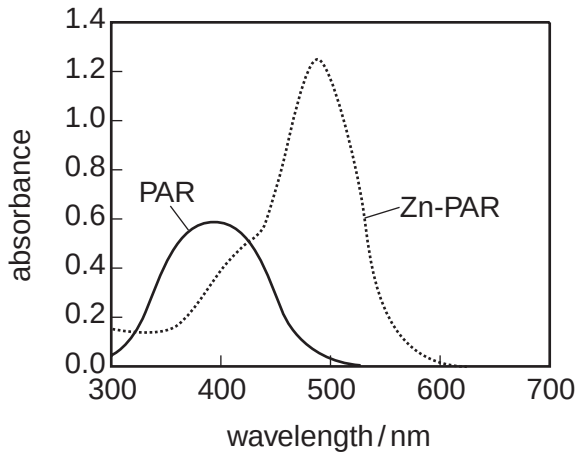
lattice energy = ... kJ mol^{-1} [3]

(d) Zinc is an essential element for plant and animal life. It is often administered in the form of a chelate, which is a complex between a metal ion and a polydentate ligand.

The rate of the reaction between zinc ions and the ligand 4-(2-pyridylazo)resorcinol, PAR, has been studied.



Both PAR and its zinc complex absorb radiation in the UV-visible region. The figure below shows their absorption spectra.



(i) Devise a suitable experimental technique for studying how the rate of this reaction varies with [Zn^{2+}(aq)].

.....

.....

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.....

.....

.....

.....

(ii) Describe a reaction you could carry out to show that PAR is a phenol.

.....

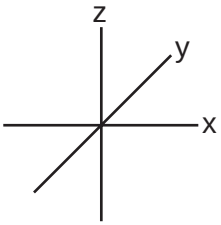
.....

[7]

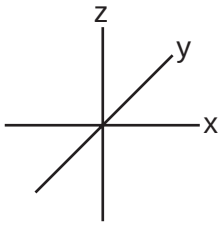
[Total: 19]

4 This question is about the bonding of covalent compounds.

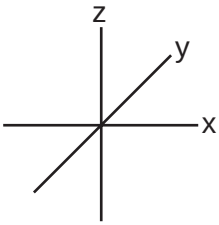
(a) On the axes below, sketch the shapes of a 1s, a 2s, and a $2p_x$ orbital.



1s



2s



$2p_x$

[3]

(b) Covalent bonding occurs when two atoms share a pair of electrons. Covalent bonding may also be described in terms of orbital overlap with the formation of σ bonds.

(i) How are the two atoms in a covalent bond held together? In your answer, state which particles are attracted to one another and the nature of the force of attraction.

.....

.....

(ii) Draw sketches to show orbital overlap that produces the σ bonding in the H_2 **and** HC*l* molecules.

H_2	HC*l*

[4]

(c) The bond in the HC*l* molecule is said to be 'polar'.

(i) What is meant by the term *bond polarity*?

.....

(ii) Explain why the HC*l* molecule is polar.

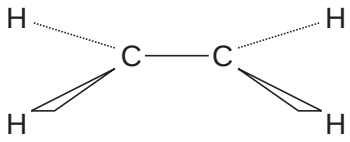
.....

.....

[2]

(d) The bonding in ethene may be described as a mixture of σ and π bonding.

Each carbon atom in ethene forms three σ bonds as shown below.



On the diagram, sketch the π bond that is also present in ethene. [1]

(e) Carbon, hydrogen and ethene each burn exothermically in an excess of air.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H_c^\ominus = -393.7\,kJ\,mol^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H_c^\ominus = -285.9\,kJ\,mol^{-1}$

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\quad \Delta H_c^\ominus = -1411.0\,kJ\,mol^{-1}$

Use the data to calculate the standard enthalpy change of formation, $\Delta H_f^\ominus$, in $kJ\,mol^{-1}$, of ethene at 298 K.

$2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$

$\Delta H_f^\ominus$ = ... $kJ\,mol^{-1}$

[3]

[Total: 13]