INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
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MARKSCHEME

November 1999

CHEMISTRY

Higher Level

Paper 2

15 pages

SECTION A

1. (a) $CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$

OR

$Cu^2 + Zn \rightarrow Zn^{2+} + Cu$ *[1]*

States not necessary to gain mark

(b) Amount of Zn $= \frac{1.20}{65.37} = 0.018$ moles

Amount of $Cu^{2+} = \frac{50}{1000} \times 0.200 = 0.010$ moles *[1]*

therefore Zn is in excess *[1]*

(c) At point A the heat being given out by the reaction is equal to the heat being lost to the surroundings. *[1]*

*Do **not** give the mark for "the reaction is finished".*

(d) Correct extrapolation to when the zinc was added. *[1]*

Give no marks if the line is extrapolated to the Y axis.

Temperature rise $= 26.7 - 17.0 = 9.7^\circ$ C *[1]*

Accept $26.7 \pm 0.1^\circ$ C giving 9.6 to 9.8° C

(e) Heat $= 9.7 \times 4.18 \times 50$ *Give credit if 51.2 g taken as mass* *[1]*

$= 2027.3$ J $= 2030$ J *Answer must be given to 3 sig. figs. to gain mark* *[1]*

Consequential markings from (d)

(f) $\Delta H = -2030 \times 100$ J

$= -203$ kJ mol^{-1} *[1]*

(g) Error $= \frac{218 - 203}{218} \times 100 = 6.9$ % *[1]*

(h) *[1 **mark**] each for any **two** valid reasons*

e.g. not carried out under standard conditions;
heat loss as polystyrene beaker did not act as an adequate insulator;
solution assumed to have same specific heat capacity as 50 g of water;
Heating of metal (Cu + excess Zn), thermometer *etc.* ignored. *[2]*

2. (a) $C_2H_5COOH + H_2O \rightleftharpoons C_2H_5COO^- + H_3O^+$

OR

$$C_2H_5COOH \overset{H_2O}{\rightleftharpoons} C_2H_5COO^- + H^+$$ *[1]*

(b) $K_a = \dfrac{[C_2H_5COO^-][H^+]}{[C_2H_5COOH]}$ *[1]*

(c) $pK_a = 4.87$ therefore $K_a = 1.35 \times 10^{-5}$

Therefore $1.35 \times 10^{-5} = \dfrac{[H^+]}{[C_2H_5COOH]} = \dfrac{[H^+]^2}{0.200}$ *[1]*

Therefore $[H^+] = \sqrt{2.70 \times 10^{-6}}$ therefore $[H^+] = 1.64 \times 10^{-3}$

Therefore pH = 2.78 *[1]*

OR

$10^{-4.87} = \dfrac{[H^+]^2}{0.200}$ *([1])*

Therefore $4.87 = 2pH + \log_{10} 0.200$

Therefore $2pH = 4.87 + 0.699$

Therefore pH = 2.78 *([1])*

Have assumed $[C_2H_5COOH]_{eqm}$ is 0.200 mol dm^{-3} **or** $[H^+] <<< [C_2H_5COOH]$ *[1]*

(d) When $[C_2H_5COO^-] = [C_2H_5COOH]$

pKa = pH = 4.87

Therefore $[C_2H_5COO^-] = 0.200$

Therefore 0.100 mols of $NaCH_3CH_2COO$ in 500 cm^3

Therefore mass $= 0.100 \times [22.99 + 36.03 + 32.00 + 5.05]$

$= 9.61$ g *[2]*

(e) When H^+ is added it combines with $CH_3CH_2COO^-$ to form the acid.

$CH_3CH_2COO^- + H^+ \rightarrow CH_3CH_2COOH$ *[1]*

When OH^- is added it reacts with the acid to form water.

$CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$ *[1]*

3. (a) Zinc does not have a partially filled d sub-level in any of its oxidation states. (must include something about oxidation states or compounds) *[1]*

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ *accept [Ar] $3d^5$* *[1]*

(c) *e.g.* V (+4 , +5) **or** Cr (+3 , + 6) **or** Mn (+4 , + 7) *[1]*

or any other correct answer
both oxidation states must be correct for the mark

(d) Formula: $[Fe(H_2O)_6]^{3+}$ *[1]*

Octahedral **or** *diagram* *[1]*

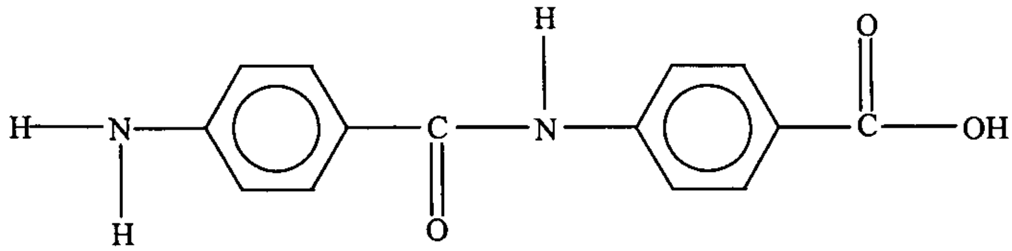
(e) Sc^{3+} does not have a partially filled d sub-level. *[1]*

The colour of Fe^{3+} is due to transitions between the d orbitals (which are split by the ligands). *[1]*

(f) Iron is added as a catalyst. *[1]*
To increase the surface area which makes it a more efficient catalyst. *[1]*

4. (a) Amino group / amine and alkanoic acid/carboxylic acid group. *[2]*

(b) (i)



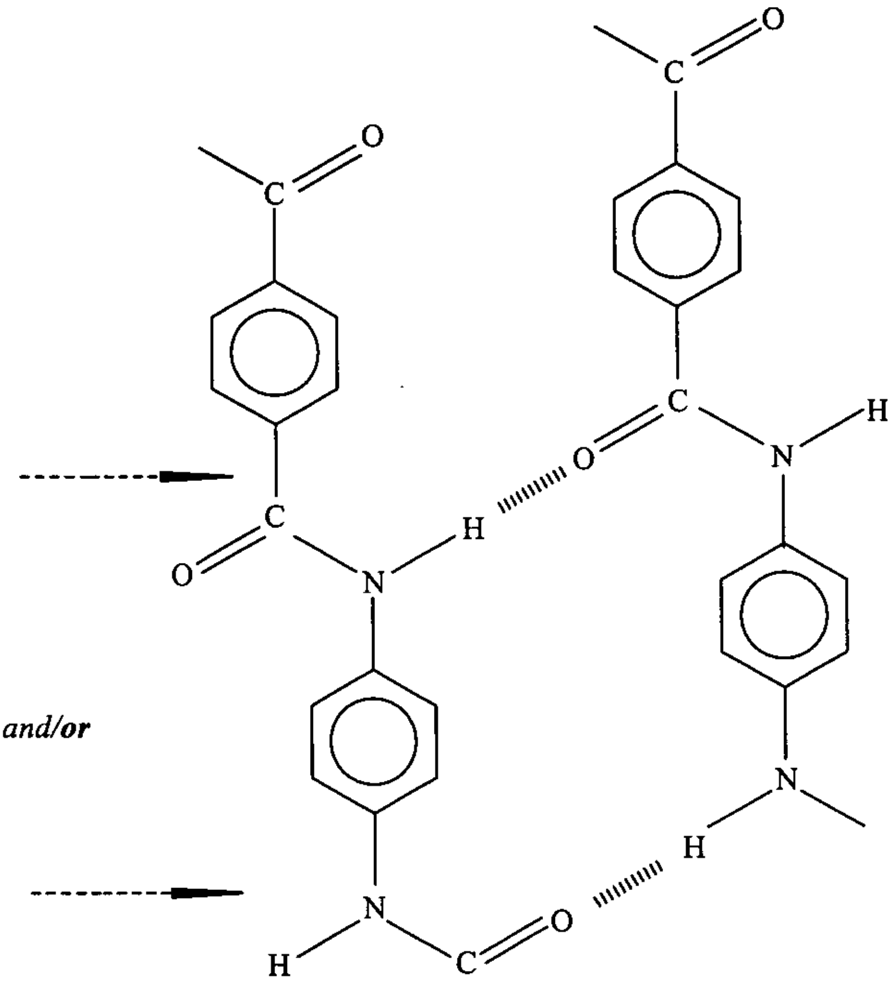
[1]

(ii) peptide bond *accept amide* *[1]*

(iii) water/H_2O *[1]*

(iv) condensation polymerisation/addition-elimination *[1]*

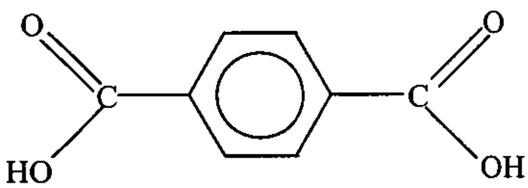
(c) (i)



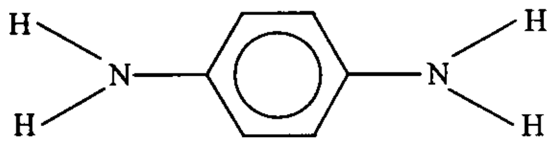
and/or

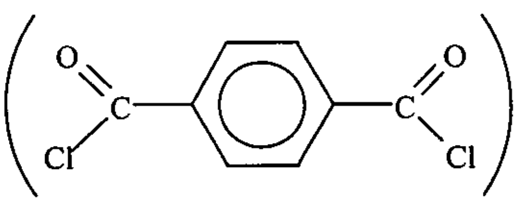
[1]

(ii)



or   *and*





[2]

(iii) Benzene rings are planar (flat) **or** the strands are kept flat by H-bonds. **[1]**
(accept either)

SECTION B

5. (a) (i) A system exhibits dynamic equilibrium when the **two opposing processes** are proceeding at **equal rates** (*i.e.* the rate of the forward reaction is equal to the rate of the reverse reaction). *[2]*

(ii) In homogeneous equilibrium **all the reactants and products** are in the **same phase**. *[2]*

(iii) A closed system is one in which there **is no exchange of matter or energy** between the system and **its surroundings**. *[2]*

(b) $K_c = \dfrac{[NH_3]^2}{[H_2]^3[N_2]}$ *[1]*

Units are: $mol^{-2}\ dm^6$ *[1]*

(c) (i) Increasing the volume has no effect on K_c for **both** reactions *[1]*
as K_c is independent of concentration. *[1]*
It will not affect the position of equilibrium of the HI reaction *[1]*
as there is no overall volume change (2 vols→2 vols). *[1]*
It will shift the position of equilibrium for the NH_3 reaction to the left (*i.e.* lower the equilibrium concentration of NH_3 relative to N_2 and H_2) *[1]*
as 4 vols of reactants give 2 vols of products. *[1]*

(ii) Lowering the temperature will move the position of equilibrium for the HI reaction to the left (more H_2 and I_2 in the equilibrium mixture) *[1]*
as the forward reaction is endothermic (heat absorbed) *[1]*
for the same reason K_c will decrease at lower temperatures *[1]*
Lowering the temperature will move the position of equilibrium for the NH_3 reaction to the right (more NH_3 in equilibrium mixture) *[1]*
because the forward reaction is exothermic (heat evolved) *[1]*
for the same reason K_c will increase at lower temperatures *[1]*

(iii) No effect on position of equilibrium *[1]*
Speeds up both forward and reverse reactions *[1]*
Does not change K_c *[1]*

(d) $\sqrt{\dfrac{1}{K_c}}$ *[1]*

$= \sqrt{\dfrac{1}{54.7}} = 0.135$ *[1]*

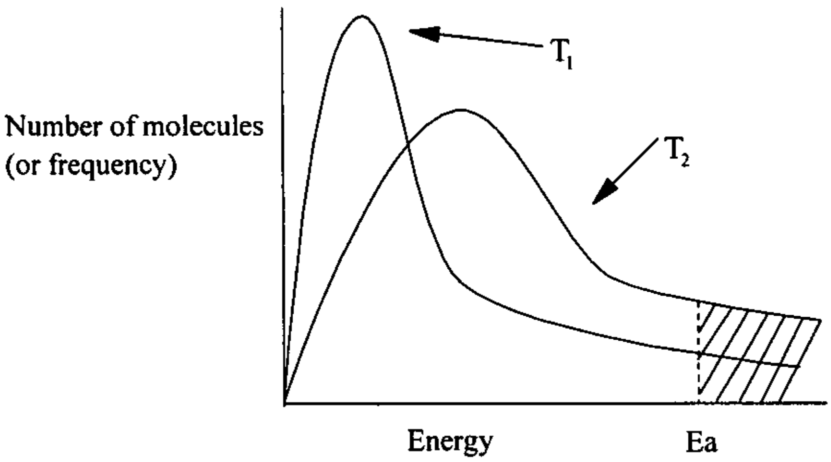
6. (a) (i) The rate constant is the constant of proportionality relating the rate of the reaction with the (reactants) as they appear in the rate expression. *[2]*

The activation energy is the minimum energy which the reactants must possess before a collision will result in a reaction. *[2]*

(ii) rate: $\text{mol dm}^{-3}\,\text{s}^{-1}$ *[1]*

k: $\text{mol}^{-1}\,\text{dm}^{3}\,\text{s}^{-1}$ *[1]*

(b) (i)



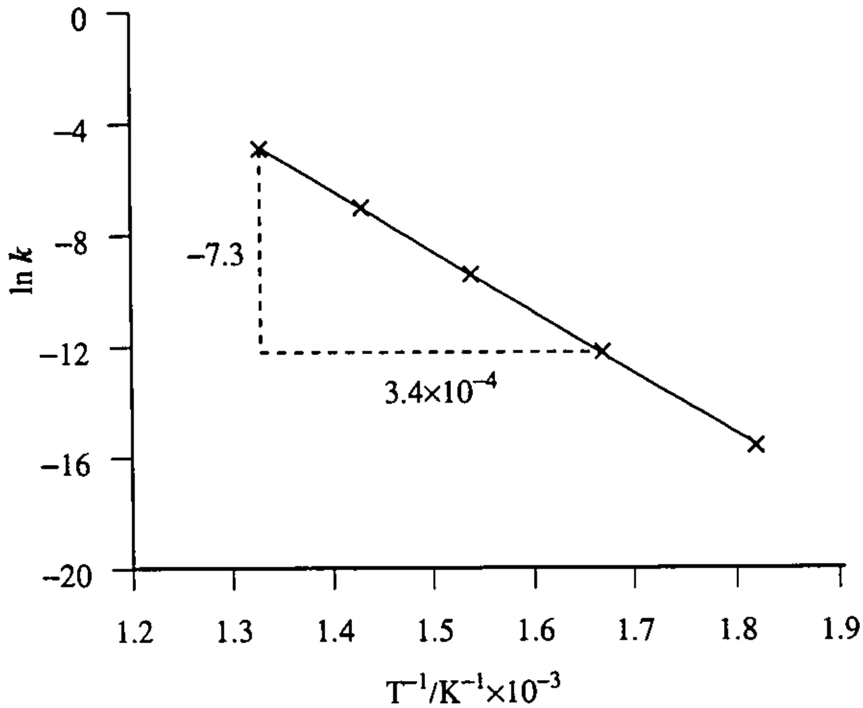
*[2 **marks**] for showing the correct Maxwell–Boltzmann curves with axes labelled.*
*[2 **marks**] for curves correctly labelled T_1 and T_2.* *[4]*

(ii) An increase in temperature increases the fraction of molecules that possess the necessary E_a. *[1]*

Showing E_a correctly on the graph. *[1]*

(iii) A catalyst provides an alternative reaction pathway with a lower E_a so that more of the reactant molecules possess the necessary energy to react. *[2]*

(c) (i) A correct plot of the data ***[2 marks]*** showing negative gradient, labelled axes in the correct range and a straight line ***[2 marks]*** *(see below).* ***[4]***



(ii) From the graph, gradient $= -\dfrac{7.3}{3.4\times10^{-4}} = -2.15\times10^{4}$ K (accept -2.0 to -2.4×10^{4}) ***[2]***

if minus sign missing or 10^4 factor missing, then ***[1 mark]***

Gradient $= -\dfrac{E_a}{R}$ ***[1]***

$E_a = 8.314\times2.15\times10^{4} = 1.79\times10^{5}\ \text{J mol}^{-1}$

$= 179$ *numerical answer* ***[1]***

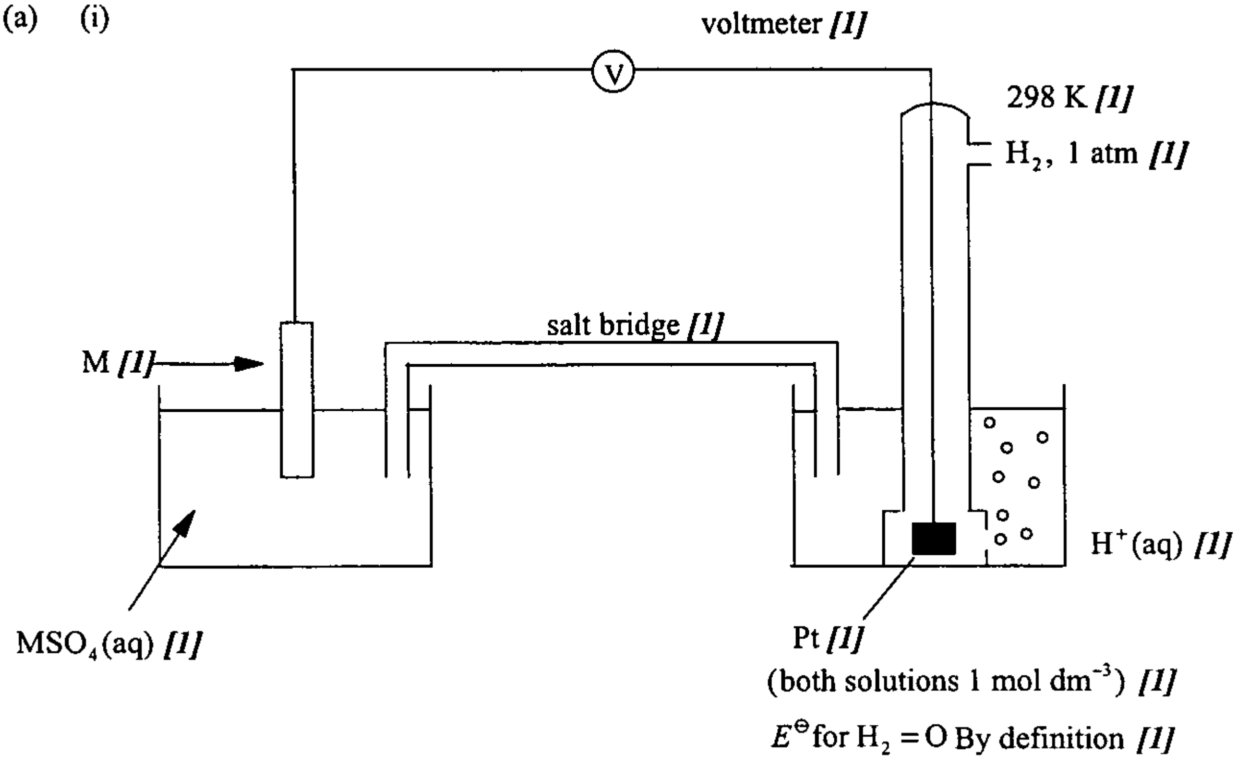
(accept 166–200)

kJ mol^{-1} *correct units* ***[1]***

(iii) The graph can be extrapolated back to the *y* axis when $T^{-1} = 0$ to give a value for $\ln A$ and hence A. ***[1]***

Particular values for $\ln k$, T^{-1}, E_a and R can be put in the Arrhenius equation to give a value for $\ln A$ and hence A. ***[1]***

7. (a) (i)



OR *description in words*

[1 mark] each for any 8 correct. *[8]*

(ii) +5 *[1]*

Reduction because there is a gain of electrons (or a decrease in oxidation number). *[1]*

both reduction and reason must be stated for mark

$MO_3^- + 6H^+ + 3e^- \rightarrow M^{2+} + 3H_2O$ *[1]*

(iii) $E^\ominus$ is higher for MO_3^- / M^{2+} than for Br_2 / Br^- (+1.09 V from Data Booklet). *[1]*

Therefore MO_3^- must be a more powerful oxidant than Br_2. *[1]*

Therefore MO_3^- will oxidise Br^- to Br_2. *[1]*

OR

For a reaction to occur E_{cell} must be positive.

For the reaction between MO_3^- and Br^- E_{cell} is +0.11 V.

Therefore this reaction can take place.

$2MO_3^- + 12H^+ + 6Br^- \rightarrow 2M^{2+} + 6H_2O + 3Br_2$ *[1]*

Mix aqueous solutions containing (1 mol dm^{-3}) MO_3^- and Br^-. *[1]*

Positive result – solution turns yellow/orange brown. *[1]*

Negative result – solution remains colourless. *[1]*

If the E_a is high the reaction may not occur/may be very slow. *[1]*

(b) Molten: $K^+ + e^- \rightarrow K$ *[1]*

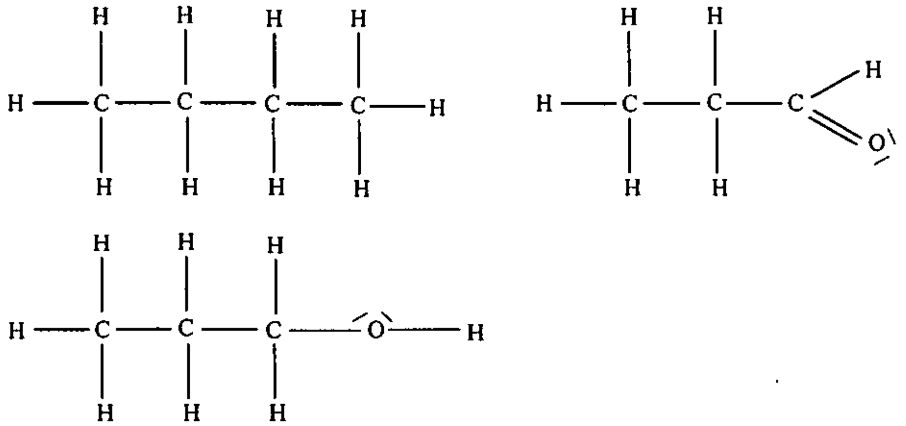
$2Br^- \rightarrow Br_2 + 2e^-$ *[1]*

Aqueous: $2H^+ + 2e^- \rightarrow H_2$ *[1]*

$2Br^- \rightarrow Br_2 + 2e^-$
(or $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$) } depending on concentration *[1]*

In aqueous solution H^+ is discharged as it is easier to reduce (more positive $E^\ominus$ or lower in electrochemical series) than K^+. In molten KBr there is only one cation present. *[2]*

8. (a) (i)



*[1 mark] for each structure, accept dot and cross diagrams but **all** outer electrons must be shown whichever method is used.* *[3]*

If the non-bonding electron pairs are not shown for propanal, do not award mark. However, do not penalise twice if they are also not shown for propan-1-ol.

(ii) butane: all four carbon atoms are sp^3 hybridised *[1]*
propanal: two sp^3 and one sp^2 *[1]*
propan-1-ol: all three are sp^3 hybridised. *[1]*

(b) $H\hat{O}C$ in propan-l-ol is just **less** than 109° *[1]*

*accept 104°–108° but **not** 109° or greater.*

$H\hat{C}O$ in propanal is approximately 120° *[1]*

(c) (i) Butane is a **non polar molecule** so the attractive forces between butane molecules are only relatively **weak van de Waals** attractions. *[2]*

(ii) Propan-1-ol contains H joined directly to the very **electronegative O atom** which results in **strong H-bonding** between molecules of propan-1-al. *[2]*

(iii) **Oxygen is more electronegative than carbon** so the bond between them will be polar resulting in **dipole:dipole** attractions between propanal molecules. *[2]*

(d) Can be explained **either** in terms of the negative ion formed:
In the RO^- ion the negative charge is localised on the O atom so there is a high negative charge density, so the ion will strongly attract an H^+ ion and return to the undissociated alcohol. In the carboxylate ion the negative charge is delocalised (*accept resonance hybrid explanation*) over the C atom and the two O atoms so the charge density is considerably reduced, decreasing the attraction of the ion for H^+.

OR

The carbonyl O withdraws electrons from the C due to its high electronegativity. The carbon in turn withdraws electrons from the hydroxyl O weakening the O–H bond in propanoic acid. *[3]*

(e) Any **three** from:
All the C–C bond lengths are equal.
All the C–C bond enthalpies are equal.
Benzene does not readily undergo addition reactions.
Two isomers of 1,2-disubstituted benzene compounds do not exist.
The enthalpy of hydrogenation or combustion of benzene is not equal to the value expected for three separate double bonds.
The ^1H NMR shift for benzene is very different to an alkane or alkene.
The ^1H NMR spectrum for benzene shows only one peak. *[3]*

or any other valid piece of evidence

All the C atoms are sp^2 hybridised. The remaining six electrons (one from a p orbital on each C atom) form a delocalised π bond over all six C atoms. This results in a planar molecule with a volume of electron density due to the delocalised π bond above and below the ring.

OR

accept a well-explained diagram *[2]*

The formation of the delocalised π bond results in extra stability for the molecule (approximately 150 kJ mol^{-1}). This explains why it does not readily undergo addition reactions (extra energy would be required to overcome the delocalised π bond) and why the enthalpy of hydrogenation and combustion is less than expected. Since all the C–C bonds are equal (in between a C–C and C=C bond) all bond lengths and strengths will be the same and there cannot be two isomers for 1,2-disubstituted benzene compounds. *[3]*

*[1 **mark**] for each matching up correct explanation with each of the three reasons given above.*