INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

M00/420/H(2) SADRU DAMJI

CHEMISTRY
HIGHER LEVEL
PAPER 2

Tuesday 16 May 2000 (afternoon)

2 hours 15 minutes

Name: MASTER KEY

Number:

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: Answer all of Section A in the spaces provided.
- Section B: Answer two questions from Section B. You may use the lined pages at the end of this paper or continue your answers in a continuation answer booklet, and indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/40	/40	/40
SECTION B QUESTION QUESTION		 /25 /25	 /25 /25	 /25 /25
NUMBER OF CONTINUATION BOOKLETS USED	....	TOTAL /90	TOTAL /90	TOTAL /90

NOTE: OWTTE: OR WORDS TO THAT EFFECT
ECF: ERROR CARRIED FORWARD

SECTION A

*Answer **all** questions from this section.*

In order to receive full credit in Section A, the method used and the steps involved in arriving at your answer must be shown clearly. It is possible to receive partial credit but, without your supporting work, you may receive little credit. For numerical calculations, you are expected to pay proper attention to significant figures.

1. (a) Automobile engines produce a variety of air pollutants at high temperatures. One of these pollutants is nitrogen(II) oxide, NO, formed in the following reaction:

$$\text{heat} + N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H^\ominus \text{ is positive}$$

(i) What is the significance of the positive value for $\Delta H^\ominus$? *[1]*

Endothermic reaction OR heat absorbed OR energy absorbed (1)
OR increase in enthalpy OR needs energy

(ii) State and explain the effect of a decrease in temperature on the value of K_c for this reaction. *[2]*

(The question is on equilibrium not the effect on rate of rxn.)

K_c decreases (1)

Since heat is removed equilibrium shifts to the left (1)
OR reverse reaction is favoured / "OWTTE"

(iii) In an experiment, the initial concentrations are $N_2(g) = 1.6 \text{ mol dm}^{-3}$ and $O_2(g) = 1.6 \text{ mol dm}^{-3}$. Calculate the concentration of the NO(g) after equilibrium is established. $(K_c = 1.7 \times 10^{-3})$ *[3]*

$$K_c = \frac{[NO]^2}{[N_2][O_2]} \quad (1)$$

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$$

[EQ] $1.6 - x \quad 1.6 - x \quad 2x$ (1)

$$\therefore K_c = \frac{(2x)^2}{(1.6-x)^2} = 17 \times 10^{-4}$$

$$\therefore [NO] = 2x = 0.065 \text{ mol dm}^{-3} \quad (1)$$

If x is ignored, and student uses 1.6, then $2x = 0.066$ } allow max 2 marks

$$\left(\frac{(2x)^2}{(1.6-x)^2} = 17 \times 10^{-4} \therefore \frac{2x}{1.6-x} = 0.0412 \quad \therefore 2x = 0.066 - 0.0412x \right.$$

$$\therefore 2.04(1)x = 0.066 \quad \therefore x = 0.03(3)$$

$$\left. \therefore 2x = 0.065 \right)$$

If x is ignored: $\frac{2x}{1.6} = 4.12 \times 10^{-2}$

$2x = 6.6 \times 10^{-2}$ if x ignored)

(MAX 2 marks if x ignored)

(This question continues on the following page)

(Question 1 continued)

(b) The depletion of ozone, O_3, in the upper atmosphere can be caused by the reaction of automobile exhaust gases, such as NO, with the ozone. The reaction between $O_3(g)$ and NO(g) has been studied and the following data were obtained at 25 °C.

Experiment	$[NO(g)] / mol\,dm^{-3}$	$[O_3(g)] / mol\,dm^{-3}$	Rate / $mol\,dm^{-3}\,s^{-1}$
1	1.00×10^{-6}	3.00×10^{-6}	0.660×10^{-4}
2	const 1.00×10^{-6}	×2 6.00×10^{-6}	×2 1.32×10^{-4}
3	3.00×10^{-6}	9.00×10^{-6}	5.94×10^{-4}
4	4.50×10^{-6}	7.20×10^{-6}	

(i) Give the rate equation for the reaction between NO(g) and $O_3(g)$, showing your reasoning. (reasoning needed for full marks) [3]

c 1 & 2: Doubling $[O_3]$ doubles rate ∴ rate ∝ $[O_3]^1$ (1)

c 1 & 3: Tripling $[O_3]$ AND tripling [NO] ⇒ rate increases by 9

∴ rate ∝ $[NO]^1$ (1)

(If NO reasoning for 2 correct orders then only (1) mark)

∴ Rate = $k[O_3]^1[NO]^1$ (1) ← (use ECF principle)

(ii) Calculate the value of the rate constant, *k*, stating its units. [2]

(use expt. #1 values) (use ECF principle)

$0.660 \times 10^{-4} = k(3.00 \times 10^{-6})^1 (1.00 \times 10^{-6})^1$ (1)

∴ $k = 2.20 \times 10^7$ $dm^3\,mol^{-1}\,s^{-1}$ (1)

(accept 2.2×10^7)

[If incorrect or no units, apply −1(U)]

(iii) Calculate the rate of the reaction for Experiment 4. [1]

(Apply ECF from (i))

$rate_4 = 2.20 \times 10^7 \times 4.50 \times 10^{-6} \times 7.20 \times 10^{-6} = 7.13 \times 10^{-4}$ ($mol\,dm^{-3}\,s^{-1}$) (UNITS NOT REQD) (1)

(12)

2. Select the substance with the higher boiling point in each of the following pairs. Explain your reasoning.

* Some candidates had problems with the idea of boiling point.

(a) C_2H_6 and C_3H_8 [3]

C_3H_8 has the higher boiling point ①

Since it has a greater M_r / greater number of electrons / greater number of carbons ①

Thus greater intermolecular forces / more energy needed ①

(b) CH_3CH_2OH and CH_3OCH_3 [3]

CH_3CH_2OH has a higher boiling point ①

due to hydrogen bonding between molecules ①

So more energy needed to separate molecules / so greater intermolecular forces ①

(6)

Boiling:
* It is not the breaking of bonds within a molecule, but energy required to separate molecules (ie overcome interparticle forces) is what the question is referring to

3. (a) In the reaction

x should be: ⇌

$$2H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq)$$

use the Brønsted-Lowry Theory to discuss the acidic and/or basic nature of water. [2]

H_2O is acidic because it is a H^+ donor (need both points for mark.)
and basic because it is a H^+ acceptor/ ①

suitable equations OR WORDS TO THAT EFFECT involving water ①.
⇒ $H_2O \longrightarrow H^+ + OH^-$; $H_2O + H^+ \longrightarrow H_3O^+$ (differ only by H^+)

(b) What is the conjugate base of the hydroxide ion, OH^-? [1]

O^{-2} OR O^{2-} OR oxide ion ① ←

(H_2O was the typical answer)

(c) State **one** method which could be used to decide whether a solution of 0.10 mol dm^{-3} acid is strong or weak. Give the results expected in each case. [3]

Electrical conductivity OR pH meter OR indicator paper or full range indicator ①
(but not litmus paper)
Strong : good conductor OR strong: low pH ①
Weak : poor conductor OR Weak: high(er) pH ① (OR lower the pH stronger the acid)
⇒ (use judgement on other methods - eg. idea of titration (curve): S.A.+SB: pH = 7 at neut
W.A.+S.B: pH > 7 " ")

(d) In a titration experiment, 40.0 cm^3 of 0.150 mol dm^{-3} NaOH was added to 60.0 cm^3 of 0.200 mol dm^{-3} $CH_3(CH_2)_3COOH$ ($K_a = 1.38 \times 10^{-5}$ mol dm^{-3}). Calculate the pH of this mixture. [4] ← (a problem)

Working must be shown. pH = 4.86 on its own (without work) only worth ① mark.

$n_{NaOH} = 0.0400\,dm^3 \times 0.150\,\frac{mol}{dm^3}$; $n_{acid} = 0.060 \times 0.200$ ①
$= 6.00 \times 10^{-3}$ mol ; $= 1.2 \times 10^{-2}$ mol

(OR) mole ratio (acid : base) = 60.0 × 0.200 : 40.0 × 0.150 = 2 : 1

Acid is in excess, and reacts to form salt ; moles acid : salt = 1 : 1 ①

$HX_{(aq)} \rightleftharpoons H^+_{(aq)} + X^-_{(aq)}$; $K_a = \frac{[H^+][X^-]}{[HX]}$ OR $[H^+] = K_a \frac{[acid]}{[salt]}$ ① award for Ka expression

(ECF)
$\therefore [H^+] = K_a$, $\therefore$ pH = 4.86 ①

Note: Weak acid calculation based on excess acid gives pH = 3.04 [3 marks max.]
Weak acid calculation based on total acid given pH = 2.89 [2 marks max.]
Solution based solely on ½ neutralisation work 3 marks only

(10)

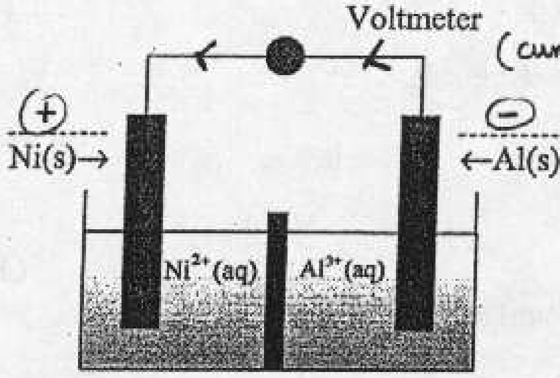
If incorrect H^+ calculated, then give a mark for correct pH calculation

(Same as $pH = pK_a + \log\frac{[salt]}{[acid]}$)
(Students MUST NOT memorise this equation!)

4. (a) Define a reducing agent in terms of electrons. [1]

A reducing agent loses (or donates) electrons (OWTTE) ①

(b) In the following representation of a cell, label each electrode with a + or a – sign, as appropriate, and draw an arrow on the connecting wire to indicate the direction of electron flow. (Refer to Table 15 of the Chemistry Data Booklet.) [2]



(current flow: Al → Ni) ①

Al ⊖, Ni ⊕ (both) ①

(c) (i) Write the balanced equation for the spontaneous reaction in the above cell. [2] balanced

$2Al_{(s)} + 3Ni^{2+}_{(aq)} \rightarrow 3Ni_{(s)} + 2Al^{3+}_{(aq.)}$ ②

→ 1 mark for species on correct sides (states not reqd)

→ 1 mark for correct coefficients Even if equation is reversed

(ii) Calculate the standard cell potential. [2] NO coefficients

$E^o_{cell} = E^o_{ox}(Al \rightarrow Al^{3+}) + E^o_{red}(Ni^{2+} \rightarrow Ni) = (+1.66) + (-0.23)$

$= +1.43$ V (accept 1.43 V) For sign ①

(If coefficients included, then $E^o_{cell} = 2.63V$)

*(–1.43V if equation reversed ECF) For value ①

*IF E° values added, then 0 mark

(d) Chromium is deposited from an acidic solution containing the dichromate(VI) ion, according to the equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 12e^- \rightarrow 2Cr(s) + 7H_2O(l)$$

How many moles of Cr(s) can be deposited by a current of 8.00 A flowing for 2.00 hours? [5] (many had no idea)

MUST provide the method.

$C = At$ ①

$= 8.00 \times 2.00 \times 60 \times 60$ (OR 7200) ①

OR = 57600 Coulombs

$*F = \frac{57600}{96480}$ OR 0.597 ①

①

$n_{Cr} = \frac{0.597}{6} = 0.0995 = 0.10(0)$ mol ①

(ECF if a different # than 6 used)

(OR) $\frac{57600}{96480 \times 6}$

(If correct answer with no working, then 4 marks max.)

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SECTION B

Answer two questions. You may use the lined pages at the end of this paper or continue your answers in a continuation answer booklet. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.

5. This question is concerned with compounds having the molecular formula C_3H_8O. (Refer to the Chemistry Data Booklet to help answer this question.)

(a) Draw the full structural formulas of the **three** possible isomers and give the name of each. *[6]*

(vague)

(b) Predict how each of these isomers would behave when reacted with limited (*i.e.* **not** in excess) acidified potassium dichromate(VI) solution and describe any **observation** that could be made. Write the structures of any organic products formed and give their names. *[8]*

(c) The infra-red spectrum of one of the three possible isomers shows an absorption band at 1000–1300 cm^{-1}, but no absorption bands above 3000 cm^{-1}. State to which of these three isomers this spectrum can be assigned and give your reasoning. *[3]*

(d) Two of these isomers give the following NMR spectra:

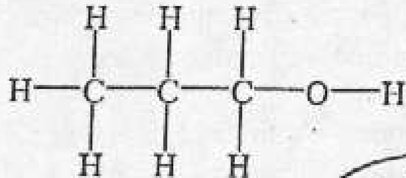
- Spectrum A with peak areas in the ratio 3:2:2:1
- Spectrum B with peak areas in the ratio 6:1:1

Assign each of these spectra to **one** of the isomers you have drawn and outline your reasoning. *[4]*

(e) Two of these isomers can be dehydrated to give the same product. Identify the two isomers and give the structure of the product. Give an equation for a characteristic reaction of the product. *[4]*

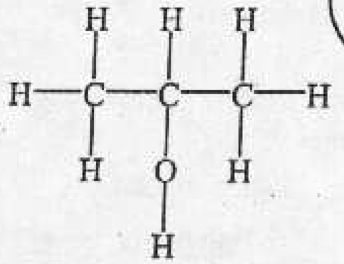
SECTION B

5. (a)



/ $CH_3-CH_2-CH_2-OH$

propan-1-ol (I)
OR 1-propanol

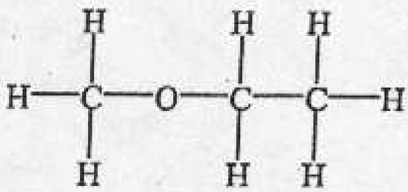


DO NOT accept lines without hydrogen atoms (penalise only on a)

/ $CH_3-\overset{H}{\underset{OH}{C}}-CH_3$

DO NOT accept propanol

propan-2-ol (II)
OR 2-propanol



/ $CH_3-O-CH_2-CH_3$

methoxyethane (III)
OR ethyl methyl ether
(accept ether / alkoxyalkane)

3 × *[1 mark]*   3 × *[1 mark]*   = ⑥

(b) (I) partially [1] oxidised *[1]* to CH_3CH_2CHO *[1]*, propanal *[1]*
(if state CH_3CH_2COOH propanoic acid instead of propanal, award [1])
(II) oxidised *[1]* to CH_3COCH_3 *[1]*, propanone *[1]*
← mark only if not in (I) above ←

(I) or (II) : orange to green ② marks   ⑧

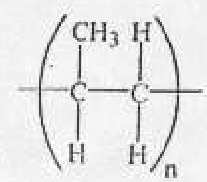
(c) alkanols show bands above 3000 cm^{-1} *[1]*
III is the choice *[1]*
since it has C–O(C) but no –O–H *[1]*   ③

(d) A is I *[1]* (1-propanol) 3 Hs in CH_3, 2 Hs in adjacent CH_2, 2 Hs in next CH_2, 1 H in OH *[1]*
B is II *[1]* (2-propanol) 6 Hs in the two CH_3s, 1 H in CH, 1 H in OH *[1]*   ④

(e) I and II *[1]*
both give $CH_3CH = CH_2$ *[1]*

	$CH_3CH = CH_2 + H_2$	$\rightarrow$	$CH_3CH_2CH_3$
OR	$CH_3CH = CH_2 + HBr$	$\rightarrow$	$CH_3CHBrCH_3$ (or $CH_3CH_2CH_2Br$)
OR	$CH_3CH = CH_2 + H_2O$	$\rightarrow$	$CH_3CHOHCH_3$ (or $CH_3CH_2CH_2OH$)
OR	$CH_3CH = CH_2 + Br_2$	$\rightarrow$	$CH_3CHBrCH_2Br$
	Reagent [1]		Product [1]

OR $CH_3CH = CH_2$ (+ high pressure, high temperature/catalyst) $\rightarrow$



OR idea of polymerisation   ← conditions not necessary for mark

reagent *[1]*   product *[1]*   ④

(25)

6. (a) (i) The oxides of magnesium and silicon have high melting points whereas the oxides of phosphorus (P_4O_6) and sulphur (SO_2) have low melting points. Explain the difference in melting points by referring to bonding and structure in each case. *[8]*

(ii) Each of the four oxides is mixed with a separate sample of pure water. For each of the oxides, state whether it is soluble or insoluble in water. For each of the oxides, state whether the **resulting liquid** is acidic, alkaline or neutral. Write an equation for each reaction. *[10]*

(b) Give the electronic configuration of the d-block element titanium. State three characteristics of d-block elements and account for each in terms of electrons. *[7]*

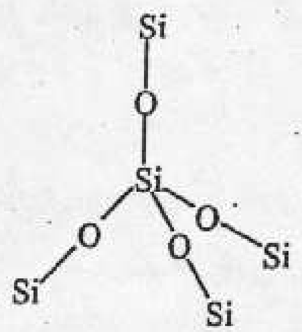
a (i): (4 structures, 4 explanations)

Revised scheme for (a)(i): 8 marks
(a)(i) MgO : ionic (1)
SiO_2 : covalent (1)
(Both are) giant structures (1)
ionic bonds strong (1)
covalent bonds strong (1)
P_4O_6 : simple molecular (1)
SO_2 : simple molecular (1)
Weak intermolecular forces/bonds (1)

6. (a) (i) **Magnesium oxide**
$Mg^{2+}O^{2-}$ / MgO ionic [1]
The ions have a strong attraction for each other [1]
OR the lattice is very strong.

Silicon oxide

(Lewis structures not asked for)



[1]

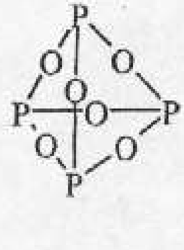
(Or described verbally: each Si atom forms covalent bonds with O)

Giant covalent/macromolecular *[1]*

P_4O_6

Trigonal Pyramid P_4O_6 with strong covalent bonds.

OR



[1]

(Or described verbally: each P atom forms covalent bonds with O)

Weak Van der Waals forces between molecules (which are easily broken) *[1]*

Question 6 (a) continued

SO_2

(allow linear O=S=O in this context) *[1]*

(Or described verbally: each S atom forms covalent bonds with O)

(Weak) **forces** (between molecules, which) **are easily broken**. *[1]*
(For P_4O_6 and SO_2 forces and breaking in either sequence.)

(8)

[Summary: Structure *[1]*, explanation *[1]*]

(ii)

Oxide	Solubility	Acidic/Alkaline/Neutral
Magnesium	Soluble	Alkaline
Silicon	Insoluble	Neutral
Phosphorus	Soluble	Acidic
Sulphur	Soluble	Acidic

4 correct = *[3]* — 4 correct = *[3]*
3 correct = *[2]* — 3 correct = *[2]*
2 correct = *[1]* — 2 correct = *[1]* — *max [6]*

Equations must be balanced
Accept ions eg. $Mg^{2+} + 2OH^-$

$MgO + H_2O \rightarrow Mg(OH)_2$ *[1]*
$P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$ (formula of acid *[1]*, balanced *[1]*) *[2]*
$SO_2 + H_2O \rightarrow H_2SO_3$ (accept $H^+ + HSO_3^-$) *[1]*

(10)

(b) Ti $1s^22s^22p^63s^23p^64s^23d^2$ / $[Ar]\ 4s^2 3d^2$ (1)

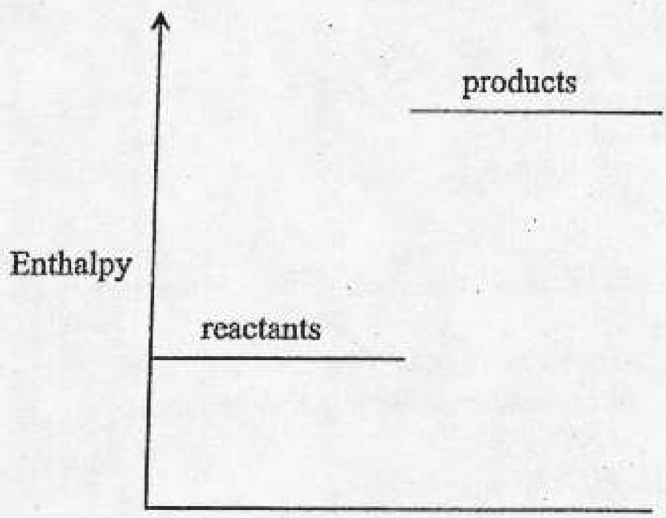
Variable valency / ox. states / OWTTE	*[1]*	removal/sharing of several electrons	*[1]*
coloured compounds	*[1]*	splitting of d orbitals, electron transitions	*[1]*
complex compounds	*[1]*	accepting of electron pairs	*[1]*
catalytic activity	*[1]*	complex formation/change of valency/can easily be oxidised or reduced	*[1]*

any three *[3]*
plus appropriate reason *[3]*

(7)

(25)

7. The enthalpy diagram for a reaction between two aqueous solutions at room temperature is shown below.



(a) (i) Give the sign of ΔH for this reaction and indicate whether it is endothermic or exothermic. State the relative strengths of the bonds in the products and reactants. *[3]*

(ii) This reaction is spontaneous at room temperature. Use this information along with that in (i) to give the signs of $\Delta G^{\ominus}$ and $\Delta S^{\ominus}$, outlining your reasoning in each case. Comment on the meaning of the sign of $\Delta S^{\ominus}$ in terms of the relative disorder of the reactants and products. *[5]*

(iii) Describe an experiment that could be conducted in a school laboratory to determine the value of ΔH (in $kJ\ mol^{-1}$) for this reaction. Show the calculations that would need to be carried out to obtain the value of ΔH. *[6]*

(iv) Outline **two** sources of error in the experimental procedure that could result in a calculated ΔH value that is *smaller* than the accepted value and suggest a way that **one** of these could be minimised. *[3]*

(v) Discuss how the spontaneity of this reaction would change as the temperature is increased from room temperature, and also as the temperature is decreased from room temperature. Outline your reasoning in each case. *[4]*

(b) Assume the reaction in (a) can be represented as

$$2A_2 + B_2 \rightarrow 2A_2B$$

(i) Derive an expression that could be used to find $\Delta H_{reaction}$ from the bond energies involved. *[2]*

(ii) Discuss the fact that $\Delta H_{reaction}$ values found from bond energies often differ from those calculated using ΔH_f values. Describe the conditions under which the best agreement is achieved between these two methods. *[2]*

7. (a) (i) $\Delta H^\ominus$ is positive [1]
Reaction is endothermic (because products are at higher energy) [1]
Bonds in reactants must be stronger than those in products (because more energy must be added than is released). [1]
(3)

(ii) $\Delta G^\ominus$ is negative [1]
because reaction is spontaneous [1]
$\Delta S^\ominus$ is positive [1]
Since $\Delta H^\ominus$ is positive, $\Delta S^\ominus$ must be positive in order to make $\Delta G^\ominus$ negative. [1]
$(\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus)$
Products must be more disordered than reactants. [1]
(5)

(iii) **Known volumes** of reactant solutions at the **same temperature** are mixed and **temperature is monitored.** [3]
Mol of limiting reactant calculated from volume and **known concentration**. [1]
$q = \Delta T \times$ mass of solution $\times C_p$ [1]
$\Delta H = q$ mol^{-1} of limiting reactant [1]
Use of insulated reaction vessel [1]
Stir the mixture [1]
max (6)

Note: *[6]* **max** which **must** include:
(a) known concentration of one volume;
(b) excess or equal reacting mols of second solution;
(c) temperature ~~rise~~ change;
(d) $q = \text{mass} \times \text{specific heat capacity} \times \Delta T$

(iv) If reactants do not react completely. [1]
If container is not insulated adequately, heat will be gained from surroundings. (note that it is an endothermic rxn) [1]
Insulate container sufficiently. [1]
(3)

(v) Reaction becomes more spontaneous as T is increased [1]
less spontaneous as T is decreased. [1]
$T\Delta S^\ominus$ term will become larger as T is raised so $\Delta G^\ominus$ will become more negative. [1]
$T\Delta S^\ominus$ term will become smaller as T is lowered so $\Delta G^\ominus$ will become less negative (or even positive as $+\Delta H^\ominus$ exceeds $T\Delta S^\ominus$). [1]
(4)

Accept arguments based on Le Chatelier's principle; watch for ECF ...

(b) (i) $\Delta H_{\text{reaction}} = 2\text{A—A bond energy} + \text{B—B bond energy} - 4\text{A—B bond energy}$ [2] (2)
[1] for correct signs *[1]* for correct coefficients
⇒ number of bonds MUST be clear

(ii) Tabulated bond energies are average values and may differ from those in specific compounds. [1]
The best agreement is achieved when few bonds are broken. [1]
(2)
OR Specified bond energies used
OR are gaseous molecules OR ....

(25)

Generally not done well

8. (a) Nitrogen forms a number of different compounds with hydrogen including

NH_3 H_2NNH_2 HNNH

(i) Write Lewis electron dot structures for N_2, NH_3, H_2NNH_2 and HNNH. [4]

(ii) Compare the bond angles between the hydrogen atoms in H_2NNH_2 and HNNH. Explain your reasoning. [3]

(no reasoning asked for) (iii) Give the hybridisation of the nitrogen in N_2, NH_3 and HNNH. [3]

(iv) One of the compounds exists in two isomeric forms. Identify the compound, draw the two isomers and compare their polarities. [4]

(Just compare; Not compare and explain)

(b) Methanoic acid, HCOOH, is a weak acid. When it loses a proton the methanoate ion, $HCOO^-$, is formed.

(i) State the number of sigma bonds and the number of pi bonds in HCOOH and describe the difference between such bonds. [4]

(ii) Compare the carbon–oxygen bond lengths in HCOOH, giving your reasoning. [2]

(iii) Compare the carbon–oxygen bond lengths in $HCOO^-$, giving your reasoning. [2]

(iv) Write two Lewis electron dot structures for the $HCOO^-$ ion and state how the bonding in the ion is related to these structures. [3]

→ H_2NNH_2 3 bonded, 1 lone pair ⇒ slightly less than 109
HNNH 2 bonded + 1 lone e⁻ pair ⇒ 120°

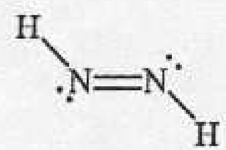
8. (a) (i) :N⋮⋮N: H:N̈:H / H   H:N̈:N̈:H / H H   H:N̈::N̈:H

→ penalise missing lone e⁻ pair once only *[1 mark]* each *[4]* (4)

(ii) Bond angles in HNNH will be slightly larger than those in H_2NNH_2. *[1]*
(CONTTE) 3 sets of electrons around the N atoms in HNNH (double bond, bond to H, lone pair) will be farthest apart at about 120° but the 4 sets in H_2NNH_2 will adopt a tetrahedral geometry with bond angles that are slightly less than 109° *[2]* (3)
(1 mark for each compd.)

(iii) N_2 – sp hybridisation, NH_3 – sp^3 hybridisation, HNNH – sp^2 hybridisation
[1 mark] each *[3]* (3)

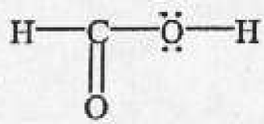
(iv) HNNH has two isomers



nonpolar   polar

[1 mark] each *[2]*
[1 mark] each *[2]* (4)

(b) (i)

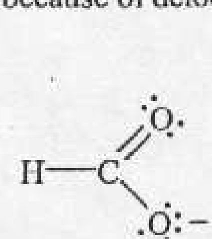


4 sigma bonds 1 pi bond *[2]*
sigma bonds lie directly between the bonded nuclei OR sigma bond strong *[1]*
pi bonds lie above and below the line between the nuclei / pi bond weak *[1]* (4)

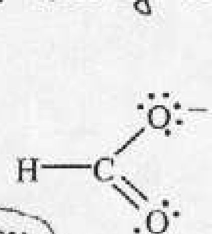
(ii) C=O shorter *[1]*
extra e⁻ pair makes bond shorter. *[1]* (2)

(iii) C—O bonds of same length *[1]*
because of delocalisation, OR idea of resonance *[1]* (2)

(iv)



AND



(negative charge omitted – no penalty)

[1]   Electrons on O omitted – max 1 mark   *[1]*   *[2]*

Actual bonding intermediate between the two/1½ bonds/π electrons spread across C—O bonds / intermediate bonding OR words to that effect *[1]* (3)

(25)