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Key

**CHEMISTRY  
STANDARD LEVEL  
PAPER 2**

Monday 18 May 2009 (afternoon)

1 hour 15 minutes

Candidate session number

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**INSTRUCTIONS TO CANDIDATES**

- Write your session 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 one question from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

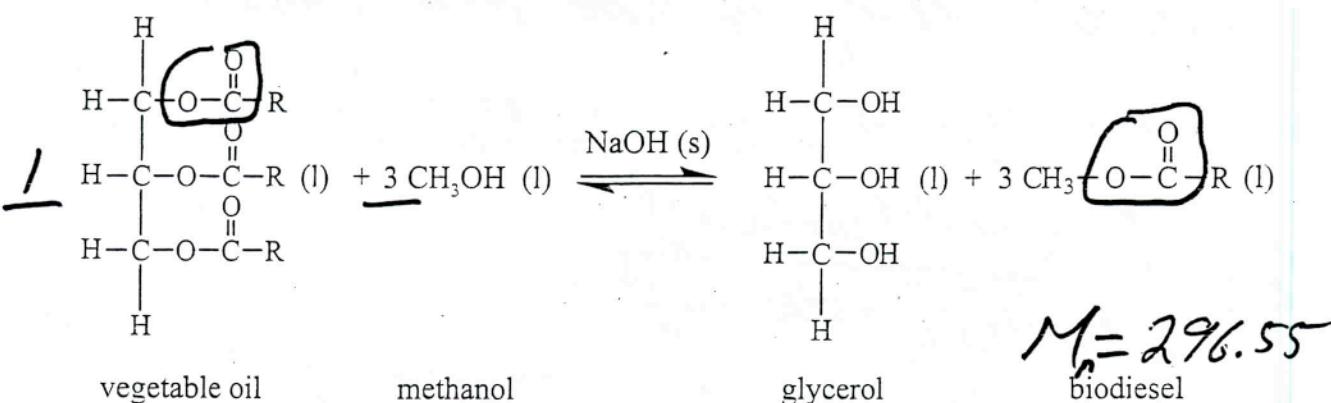


(paper 2  
May 2009)

SECTION A

Answer all the questions in the spaces provided.

1. Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



- (a) Identify the organic functional group present in both vegetable oil and biodiesel. [1]

An ester  $R-O-C(=O)-R'$

- (b) For part of her extended essay investigation into the efficiency of the process, a student reacted a pure sample of a vegetable oil (where  $R = C_{17}H_{33}$ ) with methanol. The raw data recorded for the reaction is below.

$$\text{mol} = \frac{\text{mass}}{\text{Mr}}$$

Mass of oil	= 1013.0 g
Mass of methanol	= 200.0 g
Mass of sodium hydroxide	= 3.5 g
Mass of biodiesel produced	= 811.0 g

The relative molecular mass of the oil used by the student is 885.6. Calculate the amount (in moles) of the oil and the methanol used, and hence the amount (in moles) of excess methanol used. [3]

$$\text{mol oil} = \frac{1013.0}{885.6} = 1.144 \text{ mol oil}$$

$$\text{mol CH}_3\text{OH} = \frac{200.0}{32.014} = 6.247 \text{ mol CH}_3\text{OH}$$

$$1.144 \text{ mol oil} \times \frac{3 \text{ mol CH}_3\text{OH}}{1 \text{ mol oil}} = 3.432 \text{ mol CH}_3\text{OH}$$

$$6.247 \text{ mol} - 3.432 \text{ mol} = 2.815 \text{ mol CH}_3\text{OH}$$

(This question continues on the following page) →

(Question 1 continued)

- (c) The reversible arrows in the equation indicate that the production of biodiesel is an equilibrium process.

- (i) State what is meant by the term *dynamic equilibrium*.

[1]

*Both forward and reverse reactions are occurring at the same rate.*

- (ii) Using the abbreviations [vegetable oil], [methanol], [glycerol] and [biodiesel] deduce the equilibrium constant expression ( $K_c$ ) for this reaction.

[1]

$$K_c = \frac{[\text{glycerol}][\text{biodiesel}]}{[\text{veg. oil}][\text{methanol}]}$$

- (iii) Suggest a reason why excess methanol is used in this process.

[1]

*To ensure that all the oil completely reacts.*

- (iv) State and explain the effect that the addition of the sodium hydroxide catalyst will have on the position of equilibrium.

[2]

*No effect, a catalyst only increase the rate of the reaction.*

- (d) The reactants had to be stirred vigorously because they formed two distinct layers in the reaction vessel. Explain why they form two distinct layers and why stirring increases the rate of reaction.

[2]

*Oil is nonpolar, but methanol is polar, therefore they do not mix (are not miscible). Stirring increases the reaction rate by bringing the reactants into contact with one another.*

- (e) Calculate the percentage yield of biodiesel obtained in this process.

[2]

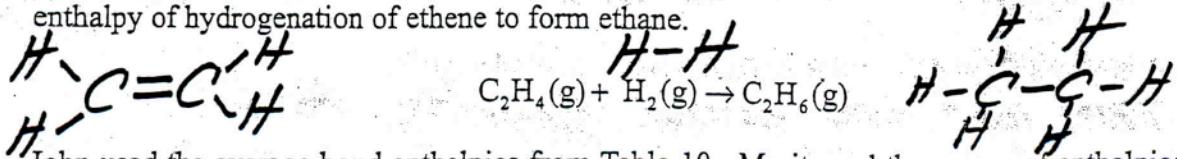
$$1.144 \text{ mol oil} \times \frac{3 \text{ mol biodiesel}}{1 \text{ mol oil}} \times \frac{296.55 \text{ g}}{1 \text{ mol}} = 1018 \text{ g}$$

$$\% \text{ Yield} = \frac{811.09}{1018 \text{ g}} \times 100 = \boxed{79.67\%}$$

(This question continues on the following page)

②.

Two students were asked to use information from the Data Booklet to calculate a value for the enthalpy of hydrogenation of ethene to form ethane.



John used the average bond enthalpies from Table 10. Marit used the values of enthalpies of combustion from Table 12.

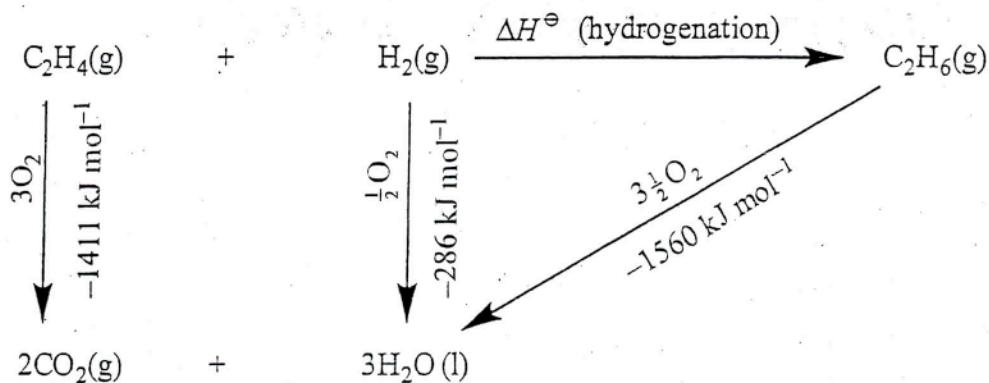
- (a) Calculate the value for the enthalpy of hydrogenation of ethene obtained using the average bond enthalpies given in Table 10.

$$\Delta H = 4(413) + (612) + (436) + 6(-413) + (-347) = \boxed{-125 \text{ kJ}} \quad [2]$$

$\Delta H_{\text{bond}}^{\text{breaking}} = \oplus$   $\Delta H_{\text{bond}}^{\text{forming}} = \ominus$

(Bonds breaking) (Bonds forming)

- (b) Marit arranged the values she found in Table 12 into an energy cycle.



Calculate the value for the enthalpy of hydrogenation of ethene from the energy cycle. [1]

$$\begin{aligned} \Delta H_{\text{rxn}} &= \sum \Delta H_{\text{comb. (reactants)}} - \sum \Delta H_{\text{comb. (products)}} \\ &= [(-1411) + (-286)] - [(-1560)] = \boxed{-137 \text{ kJ mol}^{-1}} \end{aligned}$$

(or use Hess's Law!)

- (c) Suggest one reason why John's answer is slightly less accurate than Marit's answer. [1]

Bond enthalpies are only an average amount of energy needed to break a specific bond, but can vary from molecule to molecule, such as the C-H bonds in  $\text{C}_2\text{H}_4$  &  $\text{C}_2\text{H}_6$ .

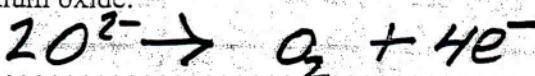
(This question continues on the following page)

Sodium oxide ( $\text{Na}_2\text{O}$ ) is a white solid with a high melting point.

- ③ (a) Explain why solid sodium oxide is a non-conductor of electricity. [1]

The ions are bound tightly to a crystal lattice and are not free to move.

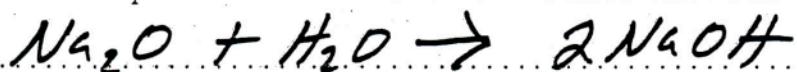
- (b) Molten sodium oxide is a good conductor of electricity. State the half-equation for the reaction occurring at the positive electrode during the electrolysis of molten sodium oxide. [1]



- (c) (i) State the acid-base nature of sodium oxide. [1]

$\text{Na}_2\text{O}$  will form a basic solution

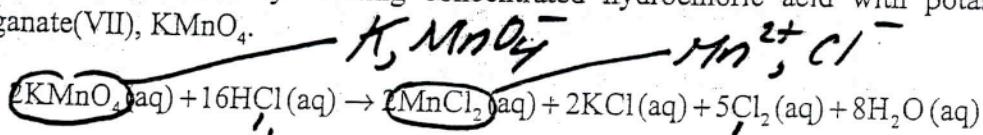
- (ii) State the equation for the reaction of sodium oxide with water. [1]



- (a) Define oxidation in terms of electron transfer. [1]

Oxidation is the loss of electrons

- (b) Chlorine can be made by reacting concentrated hydrochloric acid with potassium manganate(VII),  $\text{KMnO}_4$ .



- (i) State the oxidation number of manganese in  $\text{KMnO}_4$  and in  $\text{MnCl}_2$ . [2]



- (ii) Deduce which species has been oxidized in this reaction and state the change in oxidation number that it has undergone. [2]

Chlorine is oxidized;  
its oxidation number changes from -1 to 0.

(5) (a) (i) See diagram on page 40 (or HL p47)

(ii) mass & charge of the ions, and the strength of the mass spectrometer's magnetic field.

$$(iii) 0.0056(84) + 0.0990(86) + 0.0700(87)$$

$$+ 0.8254(88) = \boxed{87.71}$$

relative mass.

b.) (i) First ionization energy is the minimum amount of energy needed to remove one mole of electrons from one mole of gaseous atoms.

(important!)

Periodicity refers to the periodic repetition of physical and chemical properties of the elements when arranged in order of increasing atomic numbers.

(ii) Ar: \* 2, 8, 8 (electron "arrangement")  
not configuration.

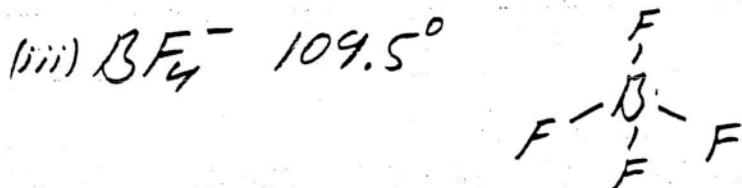
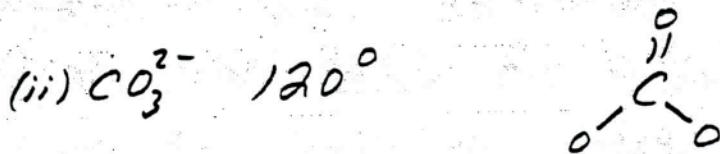
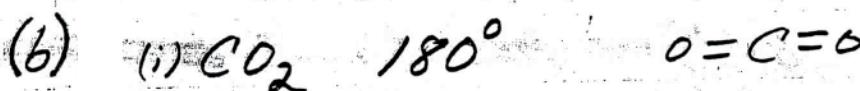
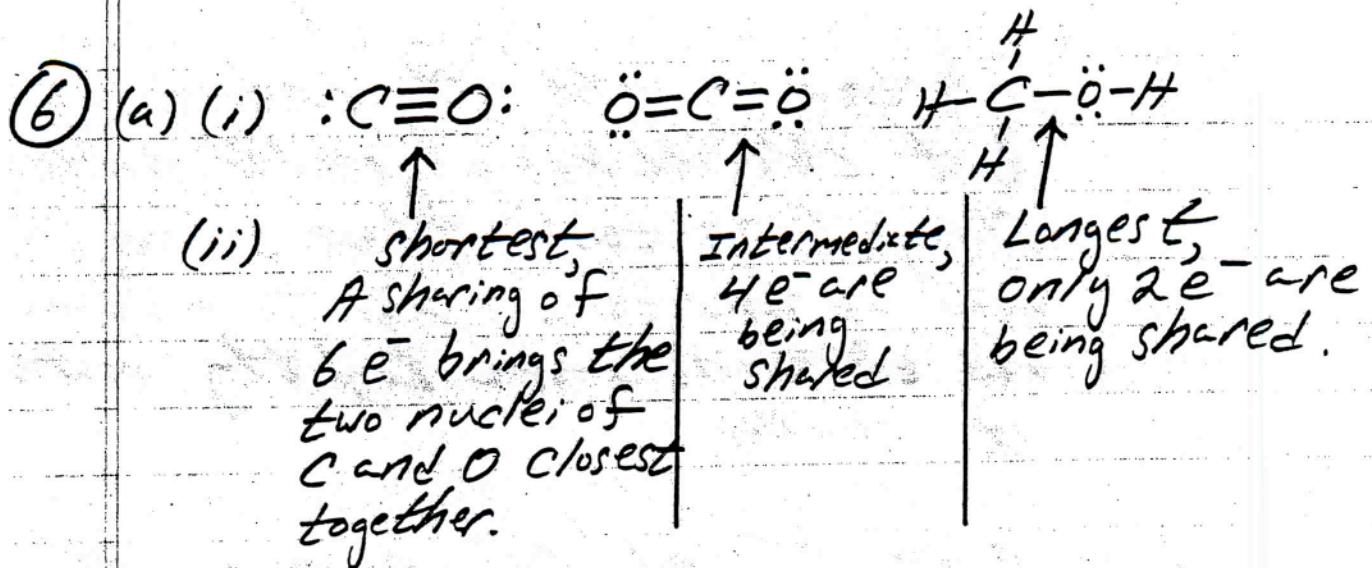
He, Ne, & Ar all have a full valence shell, which is a very stable configuration; they are also the smallest elements in their respective periods, thus the outer electrons are more tightly bound to the nucleus.

(iii) Both Na and Cl have their valence electron in the 3<sup>rd</sup> energy level, but chlorine has a greater nuclear charge (17 protons) than sodium (11 protons) and is therefore able to attract its electrons more tightly, making it smaller.

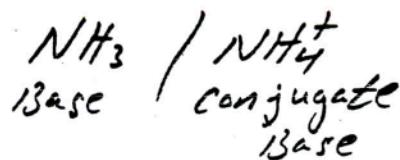
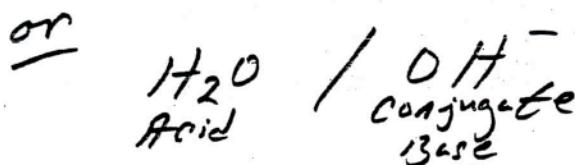
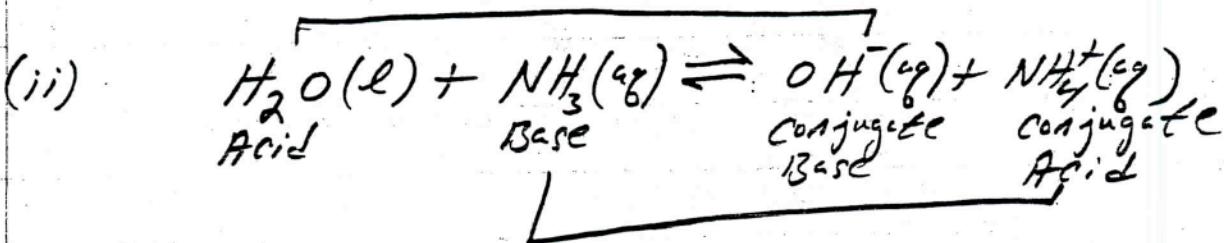
(iv) Both  $S^{2-}$  and  $Cl^-$  contain  $18e^-$ , but sulfur has 1 less proton than chlorine and is therefore not able to attract its electrons as tightly, making it the larger of the two ions.

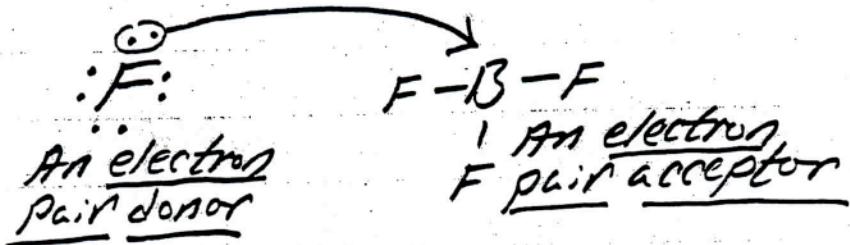
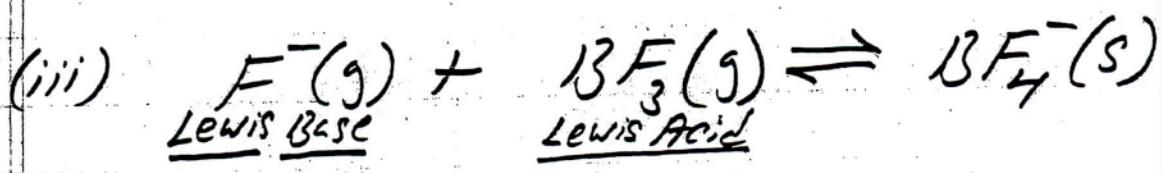
(v) As you move down the group I elements, each atom is larger with its single valence  $e^-$  belonging to a higher energy level and therefore more loosely held, making for very weak metallic bonding.

However, as you move down group 7, the increasing size increases the van der waals (dispersion) forces between these diatomic elements ( $F_2$ ,  $Cl_2$ ,  $Br_2$ ,  $I_2$ ).

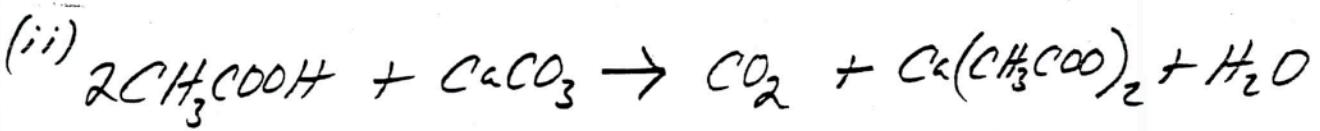


(c) (i) A Brønsted-Lowry acid is a substance that can donate a proton.





(d)(i) A weak acid will only partially ionise in aqueous solutions.



7. (a) (i) butane < propanal < propan-1-ol;  
 butane has van der Waals/London/dispersion forces;  
 propanal has dipole-dipole attractive forces;  
 propan-1-ol has hydrogen bonding;  
*imf marks are independent of the order.*

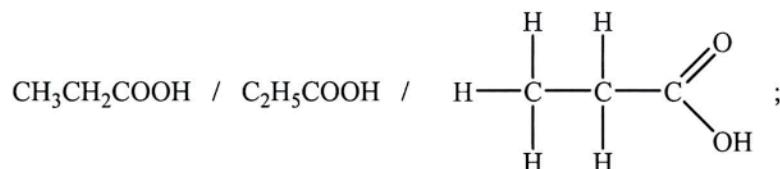
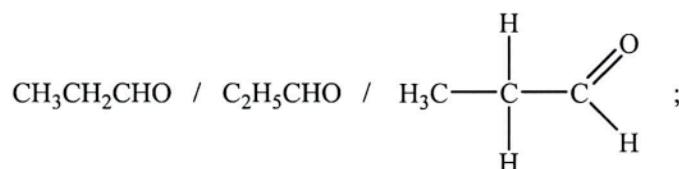
[4]

*Treat references to bond breaking as contradictions if the imfs are correct.*

- (ii) butane is least soluble;  
 it cannot form hydrogen bonds/attractive forces with water molecules;

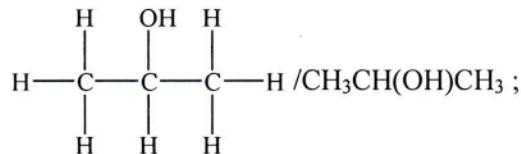
[2]

- (iii) propanal and propanoic acid;



[3]

- (iv)



[1]

- (v) secondary (alcohol);  
 propanone / acetone;

[2]

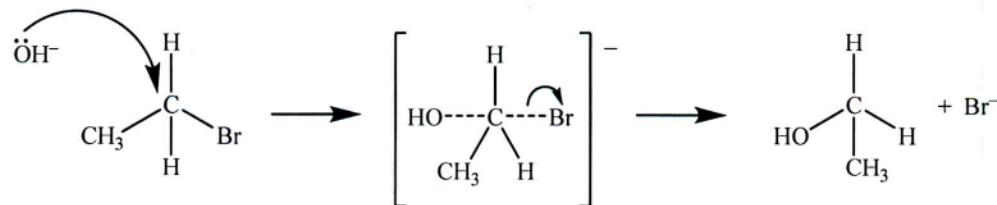
- (b) (i) hydrogen bromide / hydrobromic acid;  
*Do not accept HBr, as name is asked for.*

[1]

- (ii) sodium hydroxide / hydroxide ions (name required);  
 dilute and aqueous / dilute and warm / aqueous and warm;

[2]

(iii)

curly arrow from  $\text{OH}^-$  to C atom;*Accept from lone pair or minus sign or O. Do not award marking point if arrow originates from the H of  $\text{OH}^-$ .*

curly arrow from bond between C and Br to bromine atom on bromoethane or the transition state;

transition state including negative charge and partial bonds;

[3]

(iv) hydration of ethene / steam + ethene;

*Allow equation*

(ethanol used as) solvent/fuel/antiseptic/intermediate to form other compounds;

[2]