Energy changes

Question Paper 4

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Energy changes- Physical Chemistry
Booklet	Question Paper 4

Time Allowed: **38 minutes**

Score: **/32**

Percentage: **/100**

Grade Boundaries:

1. This question is about oxygen and its compounds.

(a) O_2 and O_3 are allotropes of oxygen.

Explain what is meant by the term *allotrope*.

.....

..... [1]

(b) A molecule of O_3 contains a dative covalent bond.

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

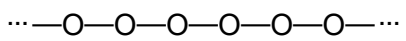
.....

..... [1]

(ii) Suggest a dot-cross diagram to show the bonding in O_3.

[2]

(c) A recent study (reported in *Proceedings of the National Academy of Sciences, USA*, 2012) has predicted that oxygen under 2TPa of pressure (1TPa = 10^{12} Pa = 10^{7} bar) can exist as the long-chain polymer shown.



At room temperature and pressure such a polymer will spontaneously turn into O_2.

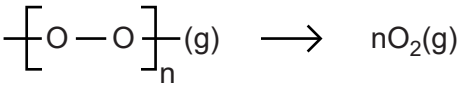
(i) What is meant by the term *bond energy*?

.....

.....

..... [3]

(ii) Calculate the energy change that accompanies the conversion of polymeric oxygen to O_2, per mole of oxygen molecules formed.



bond	bond energy / kJ mol^{-1}
O−O	144
O=O	498

energy change = ... kJ mol^{-1} [2]

(d) H^+ ions do not exist in isolation in water. They bond to water molecules to form hydronium ions, H_3O^+.

(i) Predict and explain the shape of the hydronium ion.

.....

.....

..... [2]

(ii) Which molecule with four atoms has the same total number of electrons as the hydronium ion?

..... [1]

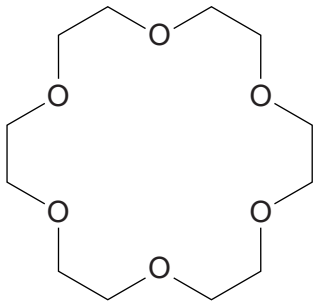
(e) A proton in an H_3O^+ ion can form a hydrogen-bond with a water molecule to form an $H_5O_2^+$ cation.

(i) Draw the $H_5O_2^+$ cation, labelling the hydrogen-bond. Include relevant lone pairs, dipoles and bond angles.

[4]

(ii) The hydronium ion, H_3O^+, may be solvated inside the macrocyclic 18-crown-6 molecule shown.

Draw the hydronium ion inside the macrocycle, showing how it is attached to the ring.



[1]

[Total: 17]

2. Magnesium powder is used to generate heat for battlefield soldiers wanting a hot drink.

9.0 g of magnesium powder is added to 30.0 g, an excess, of water.

$$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$$

(a) Calculate the amount, in mol, of magnesium.

..... mol [1]

(b) Calculate the mass of water that is in excess.

..... g [2]

(c) Calculate the volume of hydrogen gas, in dm^3, produced at room temperature and pressure.

..... dm^3 [1]

(d) Use the standard enthalpy change of formation data in Table 1.1 to calculate the standard enthalpy change of reaction for magnesium reacting with water.

Table 1.1

substance	$\Delta_f H^\ominus$ / kJ mol^{-1}
H_2O	−285.8
$Mg(OH)_2$	−924.5

..... kJ mol^{-1} [2]

(e) Calculate the heat energy, in kJ, released when 9.0 g of magnesium powder is added to 30.0 g of water.

..... kJ [1]

(f) When the magnesium powder and water are mixed, the temperature of the drink being heated can rise to 60 °C in about 10 minutes.
Calculate how much energy, in kJ, is required to heat 150 g of the drink from 15 °C to 60 °C. Assume that the specific heat capacity of the drink is $4.2\,J\,g^{-1}K^{-1}$.

..... kJ [1]

(g) How would using 9.0 g of magnesium **granules** affect the amount of energy released and the temperature reached of the drink? Explain your answer.

.....

.....

..... [2]

(h) Exothermic reactions that do **not** produce hydrogen gas are being explored.

(i) One example is mixing calcium oxide with water. Write an equation for this reaction and give the approximate pH of the resulting solution.

…… pH.....…..... [2]

(ii) Another example is the reaction of phosphorus(V) oxide with water. Write an equation for this reaction and give the approximate pH of the resulting solution.

…… pH.....…..... [2]

(iii) Calcium oxide reacts with phosphorus(V) oxide to make calcium phosphate. Write an equation for this reaction.

..... [1]

[Total: 15]