

Nitrogen & Sulfur

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Nitrogen & Sulfur
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 2

Time Allowed: 78 minutes

Score: /65

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

1 The combustion of fuels in motor vehicles, trains, aeroplanes and power stations produces the pollutant gas NO₂.

(a) Write an equation to show how NO₂ is formed in these situations.

..... [1]

(b) (i) How is the NO₂ removed from the exhaust gases of motor vehicles?

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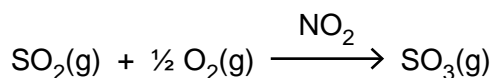
(ii) Write an equation for this process.

..... [2]

(c) Suggest whether the production of the pollutant NO₂ would be reduced if fossil fuels were replaced by hydrogen as a fuel for combustion. Explain your answer.

..... [1]

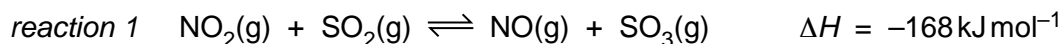
(d) In the atmosphere, NO₂ acts as a catalyst for the oxidation of SO₂ to SO₃.



(i) What is the environmental significance of this reaction?

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The oxidation takes place in two steps. The initial reaction is that between NO₂ and SO₂.



(ii) Write an equation to show how the NO₂ is regenerated in the second step of the oxidation.

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(iii) Write an expression for the equilibrium constant, *K_p* for reaction 1, stating its units.

K_p = units

(iv) If equal amounts of NO₂(g) and SO₂(g) are allowed to react at room temperature, it is found that 99.8% of the gases have been converted into products at equilibrium. Calculate a value for *K_p*.

K_p =

- (v) The temperature of the atmosphere decreases with height. How will this affect the position of the equilibrium in *reaction 1*? Explain your answer.

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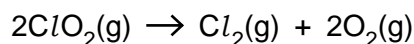
[7]

[Total: 11]

2 This question is about the properties and reactions of the oxides of some elements in their +4 oxidation state.

(a) Chlorine dioxide, ClO_2 , is an important industrial chemical, used to bleach wood pulp for making paper, and to kill bacteria in water supplies.

However, it is unstable and decomposes into its elements as follows.



(i) The chlorine atom is in the middle of the ClO_2 molecule. Using the chlorine-oxygen bond energy as 278 kJ mol^{-1} , and other values from the *Data Booklet*, calculate ΔH for the above reaction.

$\Delta H = \dots\dots\dots \text{ kJ mol}^{-1}$

(ii) Assuming the Cl-O bonds in chlorine dioxide are double bonds, predict the shape of the ClO_2 molecule. Explain your answer.

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.....

(iii) ClO_2 can be made in the laboratory by reacting KClO_3 with concentrated H_2SO_4 . Other products are K_2SO_4 , KClO_4 and H_2O .

Construct a balanced equation for this reaction. You may find the use of oxidation numbers helpful.

.....
[5]

(b) Sulphur dioxide is an atmospheric pollutant.

(i) State **two** sources of atmospheric SO_2 that arise from human activity.

.....
.....

(ii) Explain why SO_2 is a pollutant, and state an environmental consequence of this pollution.

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.....

[3]

(c) All the oxides of the elements in Group IV in their +4 oxidation state are high melting point solids except CO_2 .

(i) Explain this observation by describing the bonding in CO_2 , SiO_2 and SnO_2 .

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(ii) State the difference in the thermal stabilities of SnO_2 and PbO_2 . Illustrate your answer with an equation.

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CO_2 dissolves in water to form a weakly acidic solution containing the hydrogencarbonate ion.

(iii) Write an equation for the reaction of CO_2 with water, and write an expression for the equilibrium constant, K_c .

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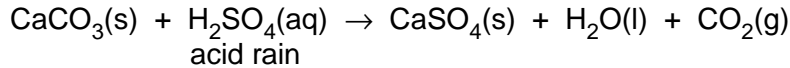
(iv) Explain the role of the hydrogencarbonate ion in controlling the pH of blood, illustrating your answer with relevant equations.

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[7]

[Total: 15]

- 3 Monuments made of marble or limestone, such as the Taj Mahal in India and the Mayan temples in Mexico, are suffering erosion by acid rain. The carbonate stone is converted by the acid rain into the relatively more soluble sulphate.



- (a) (i) Write an expression for the solubility product, K_{sp} , of CaSO_4 , stating its units.

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- (ii) The K_{sp} of CaSO_4 has a numerical value of 3×10^{-5} . Use your expression in (i) to calculate $[\text{CaSO}_4]$ in a saturated solution.

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- (iii) Hence calculate the maximum loss in mass of a small statue if 100 dm^3 of acid rain falls on it. Assume the statue is made of pure calcium carbonate, and that the acid rain becomes saturated with CaSO_4 .

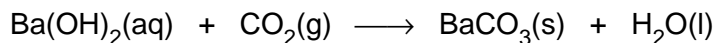
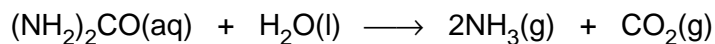
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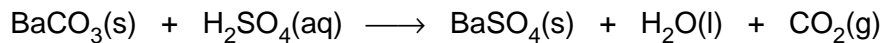
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[5]

- (b) The life of such monuments is now being extended by treating them with a mixture of urea and barium hydroxide solutions. After soaking into the pores of the carbonate rock, the urea gradually decomposes to ammonia and carbon dioxide. The carbon dioxide then reacts with the barium hydroxide to form barium carbonate.



Acid rain then converts the barium carbonate to its sulphate.



Barium sulphate is much less soluble than calcium sulphate. A saturated solution contains $[\text{Ba}^{2+}] = 9.0 \times 10^{-6} \text{ mol dm}^{-3}$.

- (i) Explain why barium sulphate is less soluble than calcium sulphate.

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- (ii) Write an expression for the K_{sp} of barium sulphate and use the data to calculate its value.

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[4]

- (c) (i) Explain what is meant by the term *lattice energy*.

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- (ii) Predict, with a reason, how the lattice energy of $BaSO_4$ might compare with that of $MgSO_4$.

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[3]

[Total: 12]

4 This question refers to the elements shown in the Periodic Table below.

								H											He
Li	Be												B	C	N	O	F	Ne	
Na	Mg												Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		

(a) From the elements shown, identify in **each** case **one** element that has the property described. Give the name or formula of the element.

(i) An element that has a molecule which contains only one atom.

.....

(ii) An element that has a molecule which contains only four atoms.

.....

(iii) The element that has the largest atomic radius.

.....

(iv) The element that is a liquid at room temperature and pressure.

.....

(v) The element in Period 3 (Na to Ar) that has the highest melting point.

.....

(vi) The element in Period 3 (Na to Ar) that forms the largest anion.

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(b) Use the elements shown opposite to answer the following questions.

(i) Give the formulae of **two** acidic oxides formed by the same element.

..... and

(ii) Give the name or formula of an oxide that is amphoteric.

.....

(iii) Identify an element whose oxide dissolves readily in water to give a strongly alkaline solution.

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(iv) Identify an element in Period 3 (Na to Ar) whose chloride dissolves in water to give a neutral solution.

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(v) Identify an element that reacts with water to give a solution that can behave as an oxidising agent.

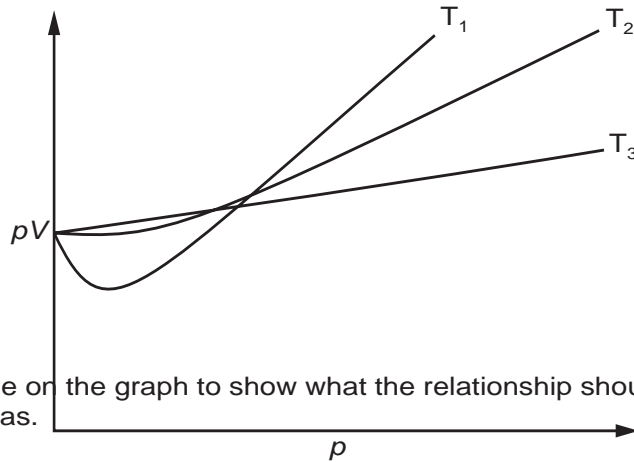
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[6]

[Total: 12]

5 The relationship $pV = nRT$ can be derived from the laws of mechanics by assuming ideal behaviour for gases.

(a) The graph represents the relationship between pV and p for a real gas at three different temperatures, T_1 , T_2 and T_3 .



- (i) Draw **one** line on the graph to show what the relationship should be for the same amount of an **ideal** gas. [1]
- (ii) State and explain, with reference to the graph, which of T_1 , T_2 or T_3 is the lowest temperature. [1]

..... [1]

(iii) Explain your answer to (ii) with reference to intermolecular forces.

..... [1]

(iv) State and explain the effect of pressure on the extent to which a gas deviates from ideal behaviour.

..... [2]

- (b) A flask with a volume of 100cm^3 was first weighed with air filling the flask, and then with another gas, **Y**, filling the flask. The results, measured at 26°C and $1.00 \times 10^5\text{Pa}$, are shown.

Mass of flask containing air = 47.930 g

Mass of flask containing **Y** = 47.989 g

Density of air = 0.00118g cm^{-3}

Calculate the relative molecular mass, M_r , of **Y**.

- (c) Although nitrogen gas makes up about 79% of the atmosphere it does not easily form compounds.

- (i) Explain why nitrogen is so unreactive.

M_r of **Y** = [4]

.....
..... [1]

- (ii) Explain why the conditions in a car engine lead to the production of oxides of nitrogen.

.....
..... [1]

- (iii) Give an equation for a reaction involved in the removal of nitrogen monoxide, NO , from a car's exhaust gases, in the catalytic converter.

..... [1]

One of the main reasons for reducing the amounts of oxides of nitrogen in the atmosphere is their contribution to the formation of acid rain.

- (iv) Write an equation for the formation of nitric acid from nitrogen dioxide, NO_2 , in the atmosphere.

..... [1]

- (v) Write equations showing the catalytic role of nitrogen monoxide, NO , in the oxidation of atmospheric sulfur dioxide, SO_2 .

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..... [2]

[Total: 15]