A2 SECTION 1 - PHYSICAL 2 - PRACTICE QUESTIONS

1 The oxides nitrogen monoxide (NO) and nitrogen dioxide (NO_2) both contribute to atmospheric pollution.

The table gives some data for these oxides and for oxygen.

	$S^{\ominus}$ / J K^{-1} mol^{-1}	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$O_2(g)$	211	0
NO(g)	205	+90
$NO_2(g)$	240	+34

Nitrogen monoxide is formed in internal combustion engines. When nitrogen monoxide comes into contact with air, it reacts with oxygen to form nitrogen dioxide.

$$NO(g) + \tfrac{1}{2}O_2(g) \longrightarrow NO_2(g)$$

(a) Calculate the enthalpy change for this reaction.

.....

.....

.....

.....

.....

(2 marks)

(b) Calculate the entropy change for this reaction.

.....

.....

.....

.....

.....

(2 marks)

(c) Calculate the temperature below which this reaction is spontaneous.

.....

.....

.....

.....

.....

(2 marks)

(d) Suggest **one** reason why nitrogen dioxide is **not** formed by this reaction in an internal combustion engine.

.....

.....

(1 mark)

(e) Write an equation to show how nitrogen monoxide is formed in an internal combustion engine.

.....

(1 mark)

(f) Use your equation from part **(e)** to explain why the free-energy change for the reaction to form nitrogen monoxide stays approximately constant at different temperatures.

.....

.....

.....

.....

.....

(2 marks)

2 The balance between enthalpy change and entropy change determines the feasibility of a reaction. The table below contains enthalpy of formation and entropy data for some elements and compounds.

	$N_2(g)$	$O_2(g)$	NO(g)	C(graphite)	C(diamond)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	0	0	+90.4	0	+1.9
$S^{\ominus}$ / J K^{-1} mol^{-1}	192.2	205.3	211.1	5.7	2.4

(a) Explain why the entropy value for the element nitrogen is much greater than the entropy value for the element carbon (graphite).

.....

.....

.....

(2 marks)

(b) Suggest the condition under which the element carbon (diamond) would have an entropy value of zero.

.....

(1 mark)

(c) Write the equation that shows the relationship between ΔG, ΔH and ΔS for a reaction.

.....

(1 mark)

(d) State the requirement for a reaction to be feasible.

.....

(1 mark)

(e) Consider the following reaction that can lead to the release of the pollutant NO into the atmosphere.

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow NO(g)$$

Use data from the table on page 4 to calculate the minimum temperature above which this reaction is feasible.

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

(f) At temperatures below the value calculated in part **2 (e)**, decomposition of NO into its elements should be spontaneous. However, in car exhausts this decomposition reaction does **not** take place in the absence of a catalyst.
Suggest why this spontaneous decomposition does **not** take place.

.....

.....

(1 mark)

(g) A student had an idea to earn money by carrying out the following reaction.

$$C(\text{graphite}) \longrightarrow C(\text{diamond})$$

Use data from the table on page 4 to calculate values for $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for this reaction. Use these values to explain why this reaction is **not** feasible under standard pressure at any temperature.

$\Delta H^{\ominus}$ .....

$\Delta S^{\ominus}$ .....

Explanation .....

.....

(3 marks)

3 Use the data below, where appropriate, to answer the questions which follow.

Standard electrode potentials	$E^{\ominus}$/V
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Br_2(aq) + 2e^- \longrightarrow 2Br^-(aq)$	+1.09
$2BrO_3^-(aq) + 12H^+(aq) + 10e^- \longrightarrow Br_2(aq) + 6H_2O(l)$	+1.52

Each of the above can be reversed under suitable conditions.

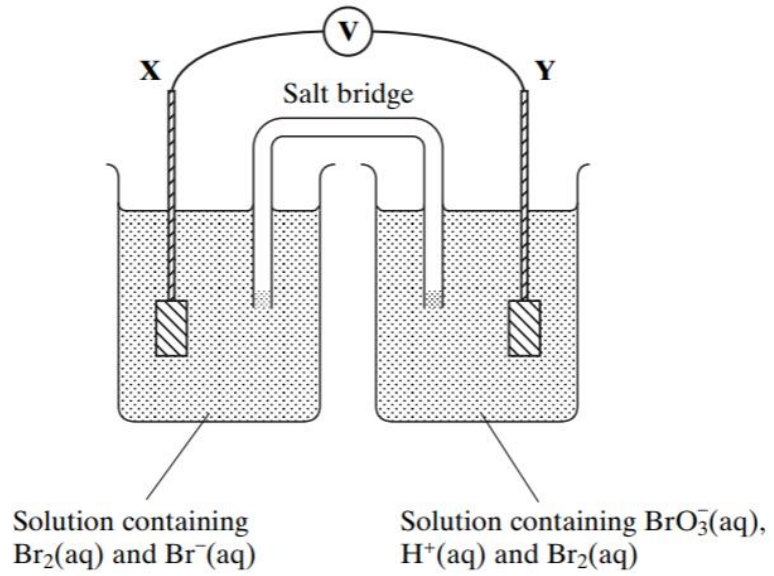
(a) State the hydrogen ion concentration and the hydrogen gas pressure when, at 298 K, the potential of the hydrogen electrode is 0.00 V.

Hydrogen ion concentration .....

Hydrogen gas pressure .....

(2 marks)

(b) A diagram of a cell using platinum electrodes **X** and **Y** is shown below.



(i) Use the data above to calculate the e.m.f. of the above cell under standard conditions.

.....

(ii) Write a half-equation for the reaction occurring at electrode **X** and an overall equation for the cell reaction which occurs when electrodes **X** and **Y** are connected.

Half-equation .....

Overall equation .....

.....

(4 marks)

4 In this question, give all values of pH to 2 decimal places.

(a) The ionic product of water has the symbol K_w

(i) Write an expression for the ionic product of water.

.....

(1 mark)

(ii) At 42 °C, the value of K_w is 3.46×10^{-14} mol^2 dm^{-6}.

Calculate the pH of pure water at this temperature.

.....

.....

.....

.....

(2 marks)

(iii) At 75 °C, a 0.0470 mol dm^{-3} solution of sodium hydroxide has a pH of 11.36

Calculate a value for K_w at this temperature.

.....

.....

.....

.....

(2 marks)

(b) Methanoic acid (HCOOH) dissociates slightly in aqueous solution.

(i) Write an equation for this dissociation.

.....

(1 mark)

(ii) Write an expression for the acid dissociation constant K_a for methanoic acid.

.....

.....

(1 mark)

(iii) The value of K_a for methanoic acid is 1.78×10^{-4} mol dm^{-3} at 25 °C.

Calculate the pH of a 0.0560 mol dm^{-3} solution of methanoic acid.

.....

.....

.....

.....

.....

(3 marks)

(iv) The dissociation of methanoic acid in aqueous solution is endothermic.

Deduce whether the pH of a solution of methanoic acid will increase, decrease or stay the same if the solution is heated. Explain your answer.

Effect on pH .....

Explanation .....

.....

.....

.....

(3 marks)

(c) The value of K_a for methanoic acid is 1.78×10^{-4} mol dm^{-3} at 25 °C.
A buffer solution is prepared containing 2.35×10^{-2} mol of methanoic acid and 1.84×10^{-2} mol of sodium methanoate in 1.00 dm^3 of solution.

(i) Calculate the pH of this buffer solution at 25 °C.

.....

.....

.....

.....

.....

(3 marks)

(ii) A 5.00 cm^3 sample of 0.100 mol dm^{-3} hydrochloric acid is added to the buffer solution in part **(c) (i)**.

Calculate the pH of the buffer solution after this addition.

.....

.....

.....

.....

.....

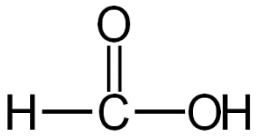
.....

.....

.....

(4 marks)

5 Formic acid is a weak acid sometimes used in products to remove limescale from toilet bowls, sinks and kettles. The structure of formic acid is:



(a) What is the systematic name of formic acid?

.....

(1 mark)

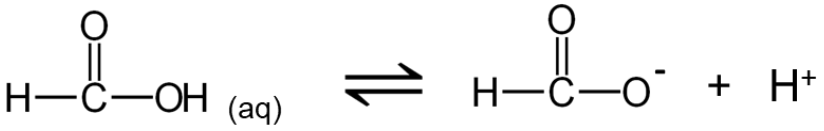
(b) What is meant by the term weak acid?

.....

.....

(1 mark)

(c) The equation for the dissociation of formic acid is:



Explain why the hydrogen atom bonded to the oxygen is the one that dissociates rather than that bonded to the carbon atom.

.....

.....

.....

(1 mark)

(d) Write an expression for K_a, the dissociation constant of formic acid.
You may use the symbol HA for formic acid and A- for the formate ion.

(2 marks)

(e) The values of pH_a a for some other weak acids are in the table.

Acid	**pK_a**
sulfuric	0.99
formic	3.8
ethanoic	4.8

Which is the strongest acid? Explain your answer.

.....

.....

.....

.....

(2 marks)

(f) Use the expression for K_a to calculate $[H^+]$ in a 1 mol dm^{-3} solution of formic acid and hence the pH of this solution.

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

(g) Limescale contains calcium carbonate, $CaCO_3$. Write an equation for the reaction of calcium carbonate with formic acid

.....

(2 marks)

(h) What mass of calcium carbonate would react with 4.5g of formic acid?

.....

.....

.....

.....

(2 marks)

(i) Bleach bases toilet cleaners contain chloric(I) acid in which the following equilibrium is set up:

$$Cl_{2\,(g)} + OH^-_{(aq)} \rightleftharpoons HClO_{(aq)} + Cl^-_{(aq)}$$

Suggest what would happen if formic acid is added to such a cleaner.

Why would this be potentially dangerous?

.....

.....

.....

.....

.....

(3 marks)

6 **(a)** Explain why the atomic radii of the elements decrease across Period 3 from sodium to chlorine.

[2 marks]

(b) Explain why the melting point of sulfur (S_8) is greater than that of phosphorus (P_4).

[2 marks]

(c) Explain why sodium oxide forms an alkaline solution when it reacts with water.

[2 marks]

(d) Write an ionic equation for the reaction of phosphorus(V) oxide with an excess of sodium hydroxide solution.

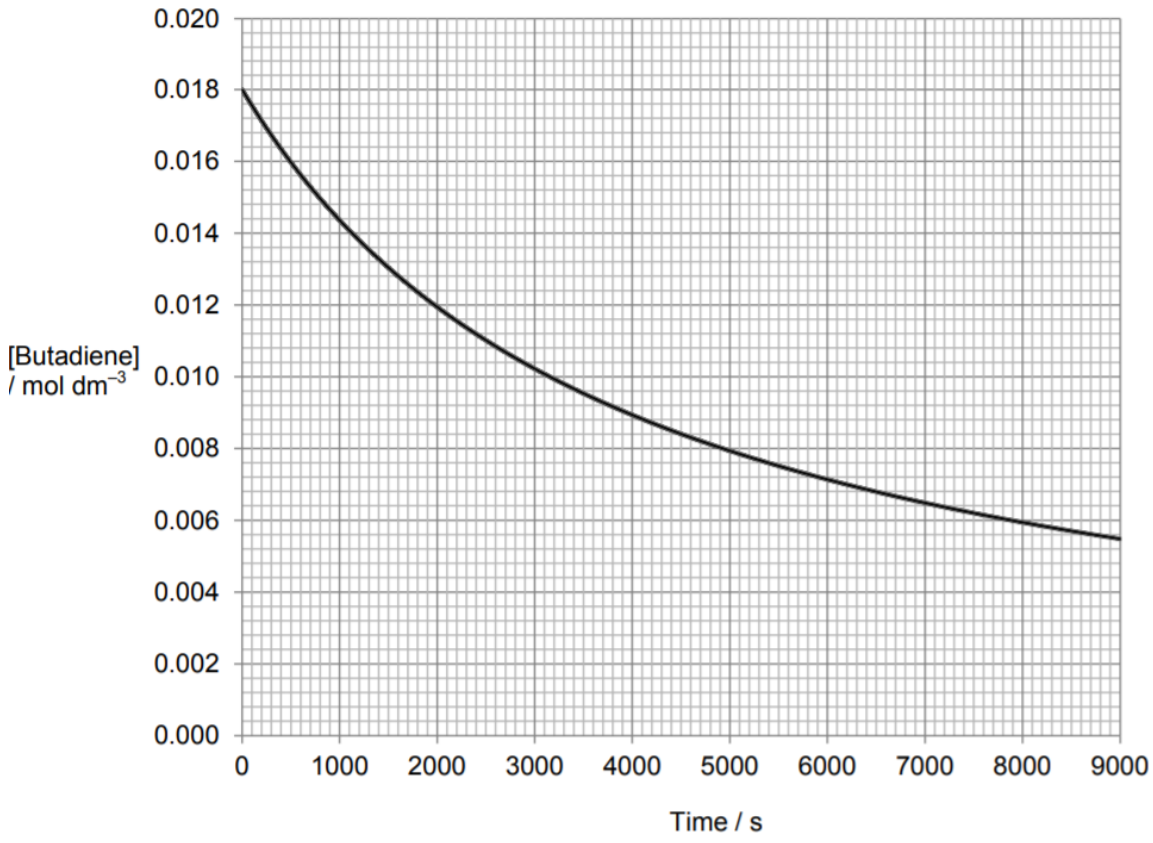
[1 mark]

7 Butadiene dimerises according to the equation

$$2C_4H_6 \longrightarrow C_8H_{12}$$

The kinetics of the dimerisation are studied and the graph of the concentration of a sample of butadiene is plotted against time. The graph is shown in **Figure 1**.

Figure 1



(a) Draw a tangent to the curve when the concentration of butadiene is 0.0120 mol dm^{-3}.

[1 mark]

(b) The initial rate of reaction in this experiment has the value 4.57×10^{-6} mol dm^{-3} s^{-1}.

Use this value, together with a rate obtained from your tangent, to justify that the order of the reaction is 2 with respect to butadiene.

[5 marks]

8 The human stomach typically contains I dm3 of hydrochloric acid (HCI) which is used to aid digestion of food. The concentration of this acid is approximately 0.01 $moldm^{-3}$.

Hydrochloric acid is a strong acid.

(a) What is meant by the term strong acid?

.....

.....

(1 mark)

(b) Write an equation for the dissociation of HCI in water.

.....

(1 mark)

(c) Calculate:

(i) the number of moles of hydrochloric acid in the stomach

.....

.....

.....

(1 mark)

(ii) the pH of the acid in the stomach

.....

.....

.....

(1 mark)

(d) Too much acid in the stomach can cause heartburn and many medicines contain antacids - compounds that react to neutralise excess acid. One such medicine contains, in the recommended dose 0.267 g of sodium hydrogencarbonate ($NaHCO_3$) and 0.160 g of calcium carbonate ($CaCO_3$).

Write equation for the reactions of:

(i) sodium hydrogencarbonate with hydrochloric acid

.....

(1 mark)

(ii) calcium carbonate with hydrochloric acid

.....

(1 mark)

(e) Using these equations, calculate how many moles of hydrochloric acid are neutralised by:

(i) the sodium hydrogencarbonate

.....

.....

.....

(1 mark)

(ii) the calcium carbonate

.....

.....

.....

(1 mark)

(iii) Calculate the total number of moles of hydrochloric acid that are neutralised by the recommended dose of the antacid.

.....

.....

.....

.....

(2 marks)

(f) (i) Calculate the number of moles of hydrochloric acid that remain in the stomach.

.....

.....

.....

(1 mark)

(ii) Calculate the pH of the stomach acid remaining. (Remember that the acid has a volume of 1 dm^3).

.....

.....

.....

(1 mark)