3. (*a*) Define rate of reaction. (5)

In the reaction of sodium thiosulfate solution with hydrochloric acid, according to the following balanced equation, sulfur precipitates as a fine, pale-yellow powder.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$$

To investigate the effect of the sodium thiosulfate concentration on the rate (*r*) of this reaction, the time (*t*), taken for a certain mass of sulfur to precipitate after the reactants were mixed, was measured at room temperature for a number of different sodium thiosulfate concentrations using a constant concentration of hydrochloric acid.

The inverse of the time for each run was taken as a measure of the initial rate of reaction ($r = 1/t$). In each run a stopwatch was started as 100 cm^3 of the sodium thiosulfate solution of known concentration were added to a reaction flask containing 10 cm^3 of the hydrochloric acid solution.

The table contains the data collected.

			Column X			**Column Y**
Run	Volume stock (30 g/L) **$Na_2S_2O_3$** solution (cm^3)	Volume water used for dilution (cm^3)	Concentration **$Na_2S_2O_3$** (g/L)	Volume **HCl** (cm^3)	*t* (s)	*r* (s^{-1})
1	100	0	30.0	10	50	
2	80	20		10	63	
3	60	40		10	83	
4	40	60		10	125	
5	20	80		10	250	
6	0	100	0	10	-	0

(*b*) Describe a method you could use to determine when the same mass of sulfur had been formed in each run. (9)

(*c*) Copy **Column X** into your answer book and fill in the missing concentrations. (6)

(*d*) (*i*) Copy **Column Y** into your answer book and fill in the missing rates, correct to three decimal places.

(*ii*) Plot a graph of concentration of sodium thiosulfate (in g/L) *versus* rate (*r*) for runs 1 to 6.

(*iii*) What can you conclude from your graph? (21)

(*e*) Describe how you could use the same reaction to investigate the effect of changing temperature on the reaction rate. (9)

2015 Q7

7. (*a*) What is a *catalyst*? (5)

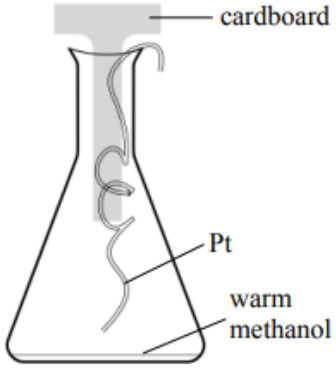
(*b*) Explain how the type of bonding in the reactants influences the rate of a chemical reaction in aqueous solution.

How could you reduce the rate of a reaction that takes place in solution? (9)

The diagram shows the oxidation of methanol using platinum wire as catalyst.

(*c*) State one observation made during this experiment.

Identify two major products of the oxidation. (9)



(*d*) What term is usually used to describe the attachment of liquid or gaseous molecules to a solid surface?

Explain how this type of interaction between the methanol and the platinum catalyst affects the rate of oxidation.

Explain how a catalyst poison like sulfur interferes with a catalyst. (9)

(*e*) Explain the term *activation energy of a reaction*.

Sketch a reaction profile diagram for an exothermic reaction labelling the axes and marking clearly on your diagram the heat of reaction (ΔH) and the activation energy for the reaction (E_A). (18)

2014 Q9 d)

(*d*) This reaction is one of several that occur in the catalytic converters fitted to car exhausts. Since the exhaust gases are in the catalytic converter of the car for a very short time (0.1 – 0.4 seconds), the rate of reaction must be very high.

Name two of the metals used as catalysts in catalytic converters.

What type of catalysis occurs?

Give **one** way that the catalysts increase the rate of reaction.

Name a substance that could 'poison' the catalysts of the catalytic converter. (15)

2013 Q4 j)

(*j*) What is meant by *heterogeneous* catalysis?

2014 Q4 g)

(*g*) Why does raising the temperature generally increase the rates of chemical reactions?

3. (*a*) Hydrogen peroxide solution is an oxidising reagent. Draw *or* describe the warning symbol put on a container of hydrogen peroxide solution to indicate this hazard. (5)

(*b*) Write a balanced equation for the decomposition of hydrogen peroxide. (6)

(*c*) Solid manganese(IV) oxide catalyst was added to a hydrogen peroxide solution at a time known exactly and the rate of production of gas was monitored as the hydrogen peroxide decomposed. Draw a labelled diagram of an apparatus that could be used to carry out this experiment. (12)

(*d*) The table shows the volumes of gas (at room temperature and pressure) produced at intervals over 12 minutes.

Time / minutes	0.0	1.0	2.0	3.0	5.0	7.0	9.0	11.0	12.0
Volume / cm^3	0.0	20.0	36.0	50.5	65.5	73.0	76.5	78.0	78.0

Plot a graph of the volume of gas produced *versus* time.

Explain why the graph is steepest at the beginning. (15)

(*e*) Use your graph to

(*i*) determine the instantaneous rate of gas production at 5 minutes,

(*ii*) calculate the total mass of gas produced in this experiment. (12)