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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Kinetics I (9)

A Level Chemistry Topic 9

5 questions · 51 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE	MARKS	PAGE
9(a)	REACTION RATES AND COLLISION THEORY	1 question · 10 marks	3
1. Q4	A Level Paper 3 November 2021	10	4
9(b)	MAXWELL-BOLTZMANN DISTRIBUTION AND CATALYSTS	3 questions · 20 marks	7
2. Q2	A Level Paper 2 June 2018	3	8
3. Q5	A Level Paper 2 June 2017	6	9
4. Q9	A Level Paper 2 October 2020	11	11
9(+)	SYNOPTIC AND MIXED QUESTIONS	1 question · 21 marks	13
5. Q6	A Level Paper 3 November 2021	21	14



QUESTIONS

5 questions · 51 marks · grouped by sub-topic



SUB-TOPIC 9(a)

REACTION RATES AND COLLISION THEORY

1 question in this sub-topic · 10 marks · lowest tariff first



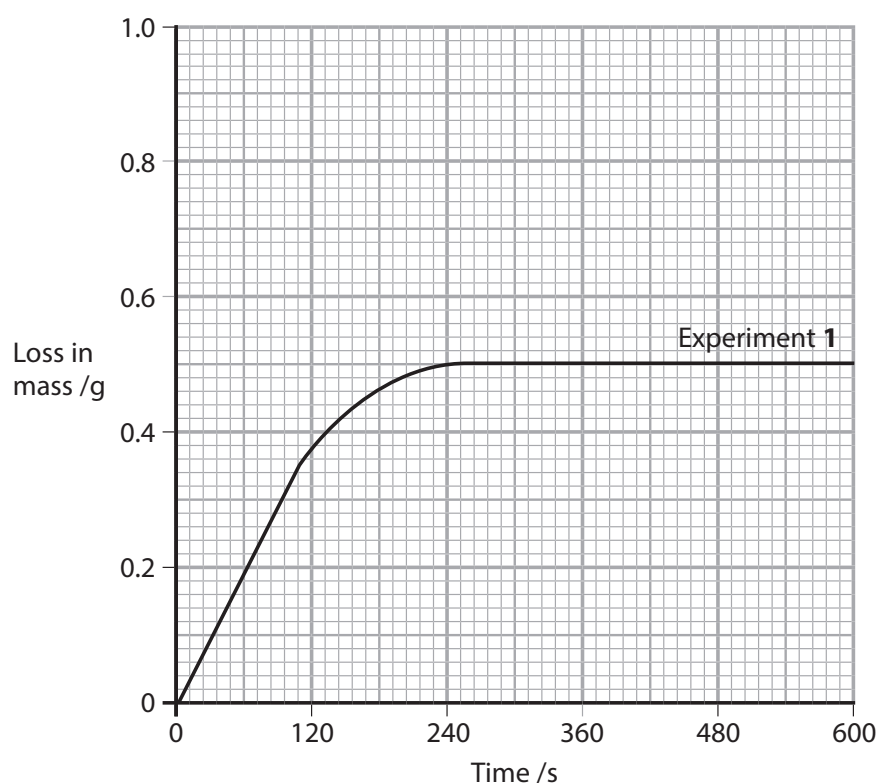
- 4 A series of experiments was carried out to investigate the factors which affect the rate of reaction between calcium carbonate and dilute hydrochloric acid.



- 50.0 cm³ of hydrochloric acid was added to 10 g of calcium carbonate (an excess) in a conical flask placed on an electronic balance.
- The loss in mass of the flask and its contents was recorded every 30 seconds for 10 minutes.
- The experiment was repeated using different sized pieces of calcium carbonate, a different concentration of hydrochloric acid or a different temperature.

Experiment	Size of calcium carbonate	Concentration of hydrochloric acid / mol dm ⁻³	Temperature / °C
1	small pieces	0.50	20
2	small pieces	0.50	60
3	one large piece	0.50	20
4	small pieces	1.00	20

The results of Experiment 1 are shown on the graph.



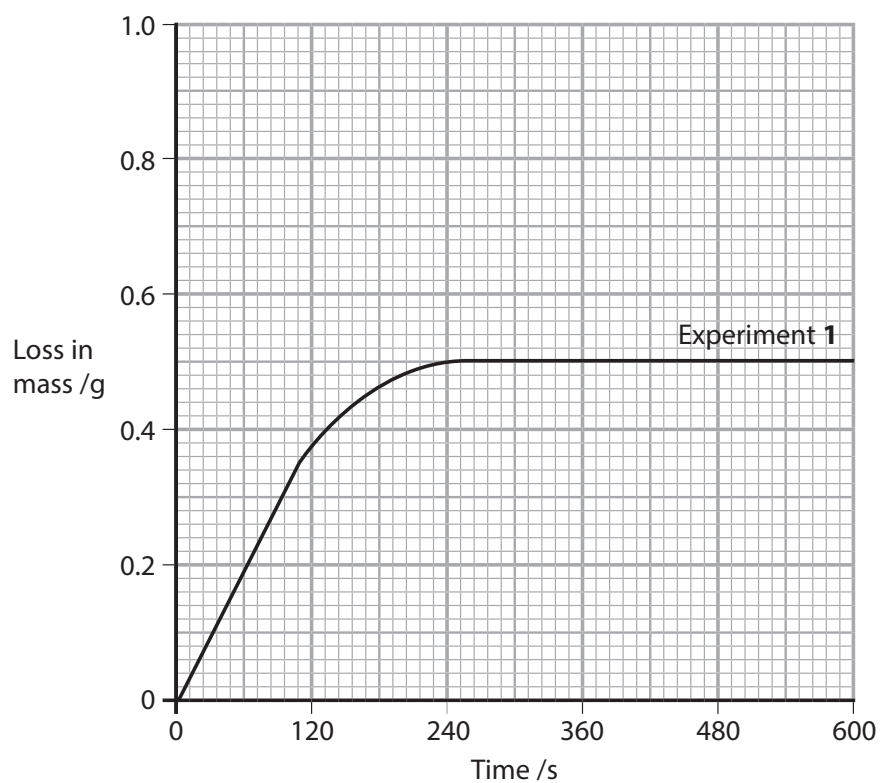
- (a) Draw curves on the graph to show the results you would expect for Experiments 2, 3 and 4. Label the curves 2, 3 and 4.

(3)



- (b) Determine the initial rate of reaction for Experiment 1.
You must show your working on the graph.
Include units in your answer.

(3)



Initial rate of reaction



- (c) A student was required to devise an alternative method of carrying out this experiment that involved collecting the gas produced.

Outline the procedure that the student could use, including a diagram and the measurements needed.

(4)

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(Total for Question 4 = 10 marks)



SUB-TOPIC 9(b)

MAXWELL-BOLTZMANN DISTRIBUTION AND CATALYSTS

3 questions in this sub-topic · 20 marks · lowest tariff first



2 This question is about how catalysts work.

(a) Gaseous reactants attach to the catalytic surface by the process of

(1)

- ☐ A absorption
- ☐ B activation
- ☐ C adsorption
- ☐ D desorption

(b) Catalytic converters of car exhaust systems have internal honeycomb structures as shown.



Explain why the honeycomb structure is used in a car exhaust system.

(2)

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(Total for Question 2 = 3 marks)

5 This is a question about catalytic converters in car exhaust systems.

(a) When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

(1)

(ii) Describe the stages by which the reaction in (a)(i) occurs in a catalytic converter.

(3)

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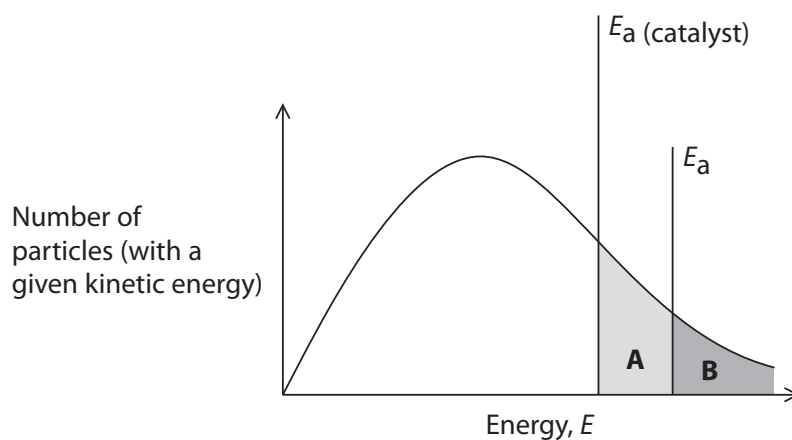
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- (b) Which area in the Maxwell-Boltzmann distribution diagram represents the **increase** in the number of particles with sufficient energy to react in the presence of a catalyst?



(1)

- ☒ **A** area A
- ☒ **B** area B
- ☒ **C** area A – area B
- ☒ **D** area A + area B

- (c) In the UK, the exhaust emissions of a petrol-fuelled vehicle must be less than 1.00 g of carbon monoxide per kilometre.

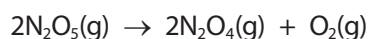
What is the maximum number of carbon monoxide molecules that can be emitted per kilometre for a vehicle to meet this regulation?

(1)

- ☒ **A** 1.37×10^{22}
- ☒ **B** 2.15×10^{22}
- ☒ **C** 6.02×10^{23}
- ☒ **D** 1.69×10^{25}

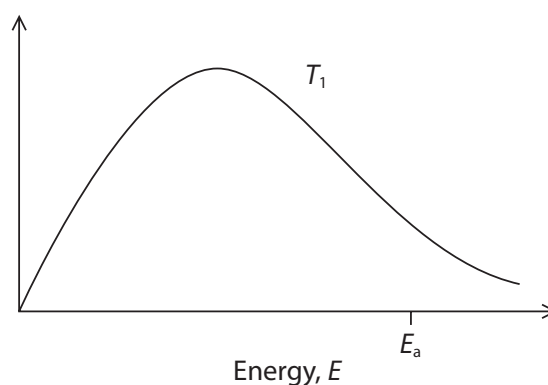
(Total for Question 5 = 6 marks)

- 9 This question is about the effect of temperature on the rate of decomposition of nitrogen(V) oxide.



- (a) The diagram shows the Maxwell-Boltzmann distribution of molecular energies for nitrogen(V) oxide at a temperature T_1 .

E_a is the activation energy of this reaction.



- (i) Give the label for the vertical axis.

(1)

- (ii) Draw a second curve on the same set of axes for the same gas at a **lower** temperature, T_2 .

(2)

- (iii) Explain, in terms of collisions and energy, why lowering the temperature decreases the rate of reaction.

(2)

- (iv) A catalyst is added to the gas.

Label the diagram above with the symbol E_{cat} to show a possible activation energy for the reaction in the presence of a catalyst.

(1)



- (b) The rate constant for the decomposition of nitrogen(V) oxide was determined at two temperatures.

Temperature / K	Rate constant / s ⁻¹
328	1.50×10^{-3}
338	4.87×10^{-3}

Calculate the activation energy for this reaction.

Include units and give your answer to an appropriate number of significant figures.

You should **not** attempt to use any graphical method to answer this question.

The Arrhenius equation relating two rate constants, k_1 and k_2 , at two different temperatures, T_1 and T_2 , can be expressed as

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

(5)

(Total for Question 9 = 11 marks)



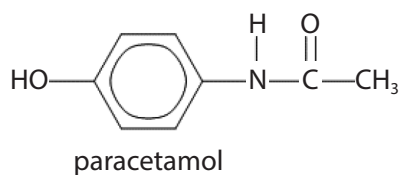
TOPIC 9

SYNOPTIC AND MIXED QUESTIONS

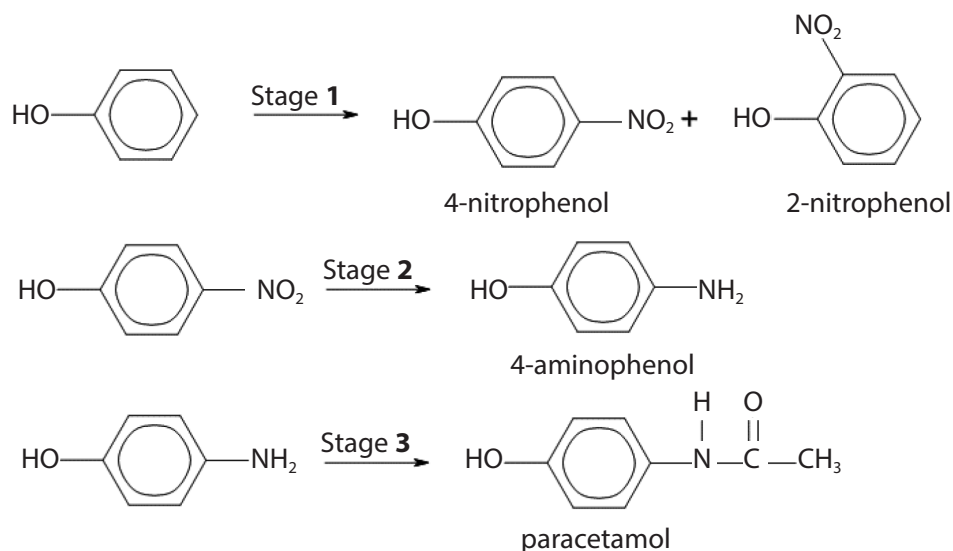
1 question in this sub-topic · 21 marks · lowest tariff first



6 This question is about the preparation and analysis of paracetamol.



Paracetamol may be prepared from phenol in three stages.



(a) In Stage 1, phenol is nitrated using dilute nitric acid.

The nitration of benzene requires concentrated nitric acid at 55°C with a catalyst of concentrated sulfuric acid.

Both these reactions are electrophilic substitution.

(i) Explain why phenol can be nitrated using milder conditions than benzene.

(2)

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- (ii) A mixture of 2-nitrophenol and 4-nitrophenol is produced in Stage 1. They are separated by steam distillation.

The boiling temperature of 2-nitrophenol is 215°C and that of 4-nitrophenol is 279°C .

Explain, in terms of intermolecular forces, why 4-nitrophenol has a higher boiling temperature than 2-nitrophenol.
You may include a diagram in your answer.

(2)

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(b) State the **type** of reagent needed to convert 4-nitrophenol into 4-aminophenol in Stage 2.

(1)

(c) The outline procedure for Stage 3 is:

- place 1.0 g of 4-aminophenol in a conical flask. Add 9 cm³ of distilled water and stir the mixture
- add 1 cm³ of ethanoic anhydride to the flask and shake the mixture until a precipitate of impure paracetamol forms
- remove the paracetamol by filtration under reduced pressure
- recrystallise the paracetamol using water as the solvent
- determine the melting temperature of the pure, dry paracetamol.

(i) Draw a labelled diagram of the apparatus used for filtration under reduced pressure.

(3)



(ii) Describe the recrystallisation process to obtain a pure, dry sample of paracetamol.

(5)

(iii) The melting temperature of pure paracetamol is 170°C.

Describe what happens to the melting temperature if the paracetamol is not pure.

(2)

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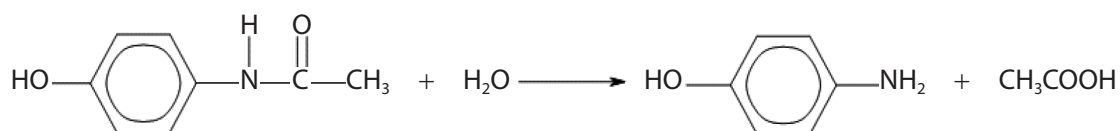


- (d) The percentage by mass of paracetamol in three brands of paracetamol tablets are shown in the table.

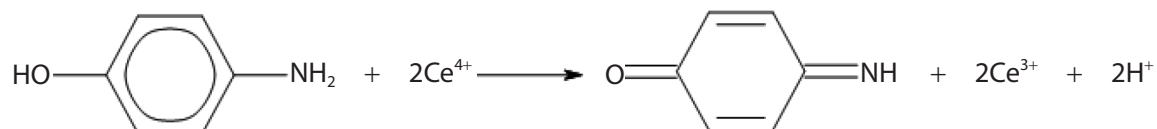
Brand of tablet	Percentage by mass of paracetamol
P	92.1
Q	93.6
R	99.7

The amount of paracetamol in a tablet can be determined using a titration with cerium(IV) ions.

The tablets are crushed and then hydrolysed in acid to form 4-aminophenol.



4-aminophenol is oxidised by cerium(IV) ions.



A tablet from one of the three brands of paracetamol was analysed following the outline procedure.

- one of the tablets was crushed and 0.500 g of the powder was added to dilute sulfuric acid
- the mixture was heated under reflux until the hydrolysis was complete
- the solution was made up to 100.0 cm³ in a volumetric flask
- 25.0 cm³ portions of the solution were titrated against 0.100 mol dm⁻³ Ce⁴⁺ using ferroin as indicator

Result

The mean titre was 16.50 cm³.

(i) Give the molecular formula of paracetamol.

(1)

(ii) Determine, by calculation, which brand of tablet was analysed.

(5)

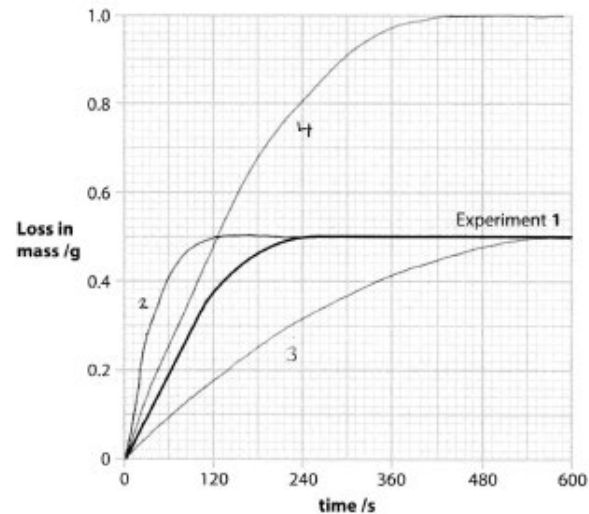
(Total for Question 6 = 21 marks)



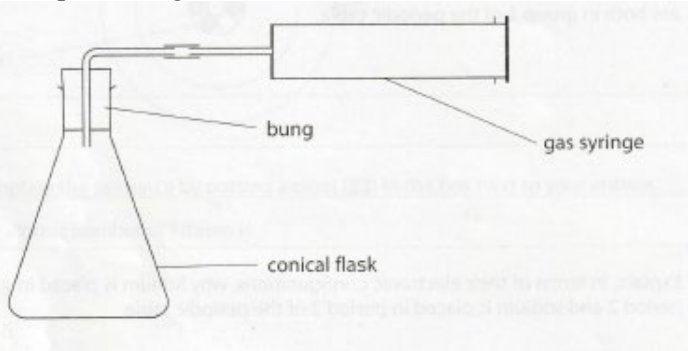
MARK SCHEMES

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Question Number	Answer	Additional Guidance	Mark
4(a)	- curve for Experiment 2 steeper than Experiment 1 and Experiment 4 and finishing at the same mass loss as Experiment 1 (1) - curve for Experiment 3 shallower than Experiment 1 and finishing at the same mass loss (1) - curve for Experiment 4 steeper than Experiment 1 and finishing at mass loss 1.0 g (1)	<u>Examples of curves</u>  Allow curve for Experiment 4 steeper than Experiments 1 and 2 and finishing at mass loss 1.0 g	(3)

Question Number	Answer	Additional Guidance	Mark
4(b)	- tangent drawn to curve when time = 0 tangent must touch curve for at least first 3 small squares on x axis and extend to at least 120 s (1) - calculation of gradient (1) - units (1)	<u>Example of tangent</u> gradient = $\frac{1.0}{300} = 3.33 \times 10^{-3}$ Allow 3.13×10^{-3} to 3.53×10^{-3} TE on tangent drawn or measurements from line on graph with no tangent Ignore SF including 1SF g s^{-1} or g/s stand alone mark	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)	An answer that makes reference to the following points: - a diagram showing (calcium carbonate in a conical) flask attached to a gas syringe / a delivery tube passing into a container of water with an upturned measuring cylinder (1) - add the hydrochloric acid and (immediately) stopper the flask (1) - record the volume of gas (1) - collected at regular time intervals (1)	<u>Example of diagram</u>  Ignore missing labels Ignore heat / water bath Do not award inclusion of a condenser Do not award test tube or beaker for collecting gas Allow carbonate added to acid and stopper the flask Allow acid in a tube / beaker in the flask and tip the flask for them to mix Allow specified time intervals Allow collected in a specified time	(4)

(Total for Question 4 = 10 marks)

Question Number	Acceptable Answer	Mark
2(a)	The only correct answer is C <i>A is incorrect because gaseous reactants attach only to the surface</i> <i>B is incorrect because this happens after adsorption</i> <i>D is incorrect because this is detachment of the products from the surface</i>	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
2(b)	An explanation that makes reference to the following: - increase surface (area) / more active sites (1) (honeycomb structure) allows gases to flow through (the exhaust) (1)	Do not award aB sorption Ignore reference to rate of reaction / remove pollutants Do not award if comments are made that refer to the structure acting like a filter for the particulates or other substances	(2)

(Total for Question 2 = 3 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	Correct equation	$2\text{NO} + 2\text{CO} \rightarrow \text{N}_2 + 2\text{CO}_2$ Accept multiples Ignore catalysts and conditions if stated	(1)
5(a)(ii)	A description that makes reference to the following points: • adsorption of gases to catalytic surface (1) • weakening of bonds (and chemical reaction) on catalytic surface (1) • desorption of products from catalytic surface (1)	Absence of reference to the catalytic surface results in a deduction of one mark Do not award absorption or “stick” Allow bonds break (and reaction occurs) on catalytic surface Ignore the type of interaction referred to between the reactants and the catalytic surface Allow ‘release’ of products from catalytic surface Allow de-adsorbed	(3)

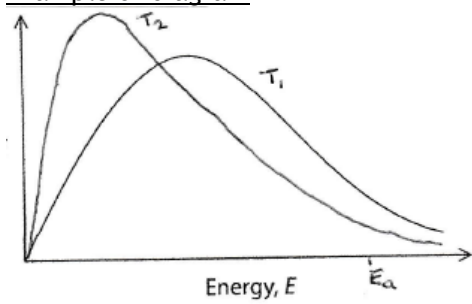


Question Number	Answer	Mark
5(b)	The only correct answer is A (area A) <i>B is not correct because this is the area representing the number of particles with sufficient energy to react in the absence of a catalyst</i> <i>C is not correct because this area subtraction does not represent the increase in the number of particles with sufficient energy to react</i> <i>D is not correct because this sum of areas represents the total number of particles with sufficient energy to react in the presence of a catalyst</i>	(1)

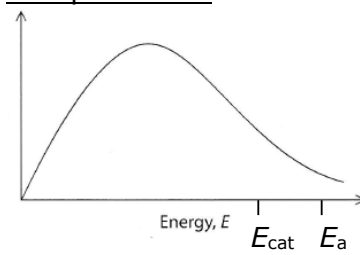
Question Number	Answer	Mark
5(c)	The only correct answer is B (2.15×10^{22}) <i>A is not correct because the molar mass of carbon dioxide has been used in the calculation instead of that of carbon monoxide</i> <i>C is not correct because this is the number of molecules that are in one mole and not one gram of carbon monoxide</i> <i>D is not correct because this is the result of incorrectly using the molar mass of carbon monoxide rather than the number of moles of carbon monoxide</i>	(1)

(Total for Question 5 = 6 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)(i)	fraction / proportion / number of molecules / particles with energy, E	Allow fraction / proportion / number of molecules / particles Allow label written on y axis on diagram	(1)
9(a)(ii)	- peak for T_2 to the left of T_1 (1) - peak for T_2 higher than T_1 and asymptote lower than T_1 line and not touching the x axis (1)	<u>Example of diagram</u>  Ignore missing label from added line Do not award M2 if added line curves upwards at the end	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	An explanation that makes reference to the following points: (at a lower temperature the) molecules / particles / collisions have lower (kinetic) energy (1) - so fewer molecules / particles / collisions have energy greater than (or equal to) the activation energy / E_a (1)	Ignore molecules / particles move more slowly Allow fewer molecules / particles have (enough energy to overcome) the activation energy Allow this shown as labelled shading on the diagram Ignore just ‘fewer successful collisions’	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(iv)	E_{cat} labelled anywhere between the energy corresponding to the highest point of the peak and to the left of E_a	<u>Example of label</u>  Allow other clear labels for E_{cat}	(1)

Question Number	Answer	Additional Guidance	Mark
9(b)	- substitution of numbers into expression (1) - evaluation of k_2/k_1 or $\ln k_2/k_1$ and $1/T_1 - 1/T_2$ (1) - rearrangement of expression (1) - evaluation of expression (1) - answer given to 2/3 SF and corresponding units (1)	<u>Example of calculation</u> $\ln \frac{4.87 \times 10^{-3}}{1.50 \times 10^{-3}} = \frac{-E_a}{8.31} \left(\frac{1}{338} - \frac{1}{328} \right)$ $k_2/k_1 = 3.2467 \text{ or } \ln k_2/k_1 = 1.1776$ Allow 487/150 for $\ln k_2/k_1$ and $1/T_1 - 1/T_2 = (-)9.0201 \times 10^{-5}$ Allow $(-)5/55432$ for $(-)9.0201 \times 10^{-5}$ e.g. $E_a = \frac{1.1776 \times 8.31}{9.0201 \times 10^{-5}}$ or $\frac{E_a}{R} = \frac{1.1776}{9.0201 \times 10^{-5}} / = 13056$ $E_a = 108\,493$ TE on $\ln(k_2/k_1)$ and $1/T_1 - 1/T_2$ $= (+)108\,000 / 110\,000 \text{ J mol}^{-1}$ or $(+)108 / 110 \text{ kJ mol}^{-1}$ Do not award negative value Expression may be rearranged before any evaluation Correct answer to 2/3 SF and units with no working scores (5)	(5)

(Total for Question 9 = 11 marks)

Total for Paper = 80 Marks

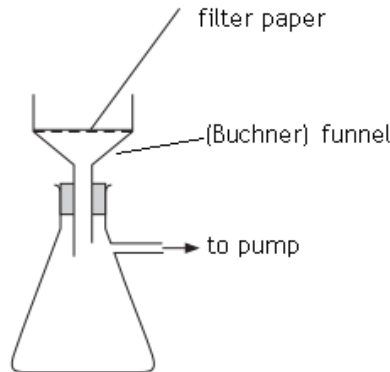


Question Number	Answer	Additional Guidance	Mark
6(a)(i)	An explanation that makes reference to the following points: - the electron density of the (benzene) ring is greater in phenol (than in benzene) (1) - because the lone pair (of electrons) on oxygen and overlaps with the pi cloud / delocalised electrons / delocalised system (1)	Allow lone pair (of electrons) on oxygen feeds into / donates into / interacts with the delocalised electrons / system Ignore electron pushing effect of OH	(2)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	An explanation that makes reference to the following points: - they both form hydrogen bonds (1) - in 4-nitrophenol the hydrogen bonds join molecules in a straight chain / at both ends / at opposite ends (of the molecule so are stronger) or 2-nitrophenol forms intramolecular hydrogen bonds / forces / interactions (so fewer intermolecular hydrogen bonds) (1)	Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces Allow 4-nitrophenol forms stronger intermolecular hydrogen bonds / forces / interactions Allow in 2-nitrophenol the hydrogen bonds join 2 molecules together / form a dimer (so there are fewer / weaker hydrogen bonds) Allow in 2-nitrophenol the hydrogen bonds are on the same side (of the molecule)	(2)



Question Number	Answer	Additional Guidance	Mark
6(b)	reducing agent / reductant	Ignore tin and concentrated hydrochloric acid Do not award any other named reducing agent	(1)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	- side-arm flask with label 'to pump' / drawing of pump (1) (Buchner) funnel with perforations and bung around neck of funnel (1) flat filter paper (over perforations) (1)	<u>Example of diagram</u>  filter paper (Buchner) funnel to pump Ignore just 'suction' Allow funnel joined to flask with 'Quickfit' joint / no gap Do not award fluted filter paper / filter paper that extends up the sides of the funnel	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	A description that makes reference to the following points: - dissolve crystals in the minimum (amount / volume) (1) - of hot water / solvent (1) - filter hot and allow to cool (1) - filter and wash with a small amount of (cold) solvent (1) - dry crystals between filter papers / in a desiccator / in a warm oven (1)	Allow add / put for dissolve Do not award wash for dissolve Penalise use of incorrect solvent once only Allow M3 if hot is omitted and is mentioned in M2 Do not award filter to remove soluble impurities Stand alone mark Allow other suitable methods of drying Do not award reference to crystals mixed with a drying agent	(5)

Question Number	Answer	Additional Guidance	Mark
6(c)(iii)	An answer that makes reference to the following points: - melting temperature is lower (1) - it melts over a range of temperatures (1) or the melting temperature is not sharp	Allow a specified range of temperatures	(2)



Question Number	Answer	Additional Guidance	Mark
6(d)(i)	$\text{C}_8\text{H}_9\text{NO}_2$	Allow the symbols, with subscripts, in any order e.g. $\text{C}_8\text{H}_9\text{O}_2\text{N}$ Allow large numbers but not superscripts Ignore any other formulae as working	(1)



Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	- calculation of amount of Ce^{4+} (1) - calculation of amount of paracetamol in 25.0 cm^3 (1) - calculation of amount of paracetamol in 100.0 cm^3 (1) - calculation of molar mass of paracetamol and mass of paracetamol in 1 tablet (1) - calculation of percentage of paracetamol in 1 tablet and conclusion (1)	<u>Example of calculation</u> amount Ce^{4+} used = $\frac{16.5 \times 0.100}{1000}$ = $0.00165 / 1.65 \times 10^{-3} \text{ (mol)}$ amount paracetamol in 25.0 cm^3 = $\frac{0.00165}{2}$ = $0.000825 / 8.25 \times 10^{-4} \text{ (mol)}$ TE on M1 amount paracetamol in 100.0 cm^3 = 4×0.000825 = $0.00330 / 3.30 \times 10^{-3} \text{ (mol)}$ TE on M2 molar mass of paracetamol, $\text{C}_8\text{H}_9\text{NO}_2$ = $(8 \times 12) + (9 \times 1) + 14 + (2 \times 16) = 151$ and mass of paracetamol in 1 tablet = $0.00330 \times 151 = 0.4983 \text{ g}$ TE on M3 and (d)(i) percentage of paracetamol = $\frac{0.4983}{0.500} \times 100 = 99.66 \text{ (\%)}$ and the tablet was from Brand R TE on M4 provided $M4 < 0.500 \text{ g}$ Ignore SF except 1 SF	(5)

(Total for Question 6 = 21 marks)

