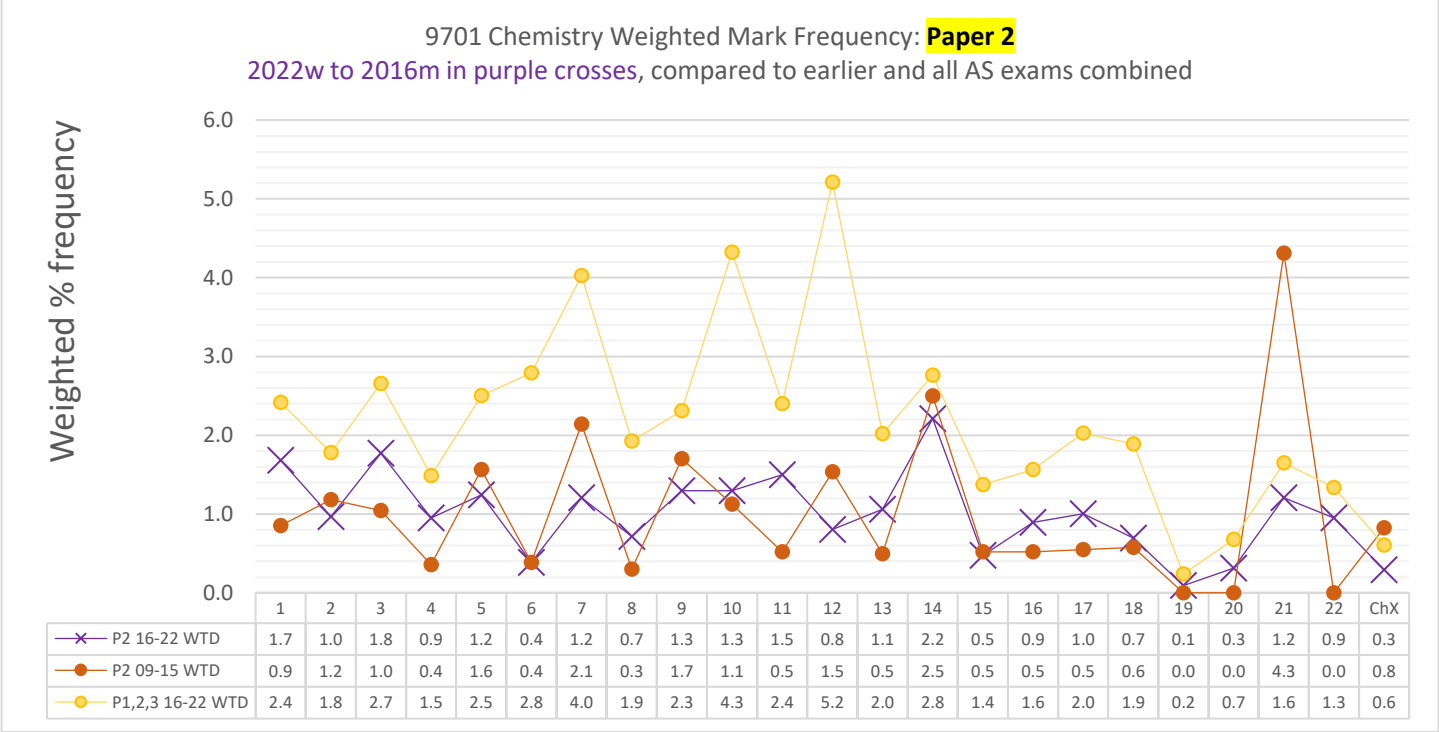
Name: Class: Date:

ALvl Chem 8 EQ P2 22w to 09s Paper 2 Reaction kinetics 50marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper 2 Topic 8 Checklist Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	50		4	5	13	20	25	38	50
Time @75s/mark (minutes)	63		5	6	16	25	31	47	63



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	ChX
P2 16-22 WTD	1.7	1.0	1.8	0.9	1.2	0.4	1.2	0.7	1.3	1.3	1.5	0.8	1.1	2.2	0.5	0.9	1.0	0.7	0.1	0.3	1.2	0.9	0.3
P2 09-15 WTD	0.9	1.2	1.0	0.4	1.6	0.4	2.1	0.3	1.7	1.1	0.5	1.5	0.5	2.5	0.5	0.5	0.5	0.6	0.0	0.0	4.3	0.0	0.8
P1,2,3 16-22 WTD	2.4	1.8	2.7	1.5	2.5	2.8	4.0	1.9	2.3	4.3	2.4	5.2	2.0	2.8	1.4	1.6	2.0	1.9	0.2	0.7	1.6	1.3	0.6

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Silver**" (25%) in the same topic in **Paper 1**, which tend also to be easier questions, as well as ""**Silver**" (25%) in the same topic, if it exists, in Paper 3.

8 Reaction kinetics

8.1 Rate of reaction

Learning outcomes

Candidates should be able to:

1 explain and use the term rate of reaction, frequency of collisions, effective collisions and non-effective collisions

2 explain qualitatively, in terms of frequency of effective collisions, the effect of concentration and pressure changes on the rate of a reaction

3 use experimental data to calculate the rate of a reaction

8.2 Effect of temperature on reaction rates and the concept of activation energy

Learning outcomes

Candidates should be able to:

1 define activation energy, E_A, as the minimum energy required for a collision to be effective

2 sketch and use the Boltzmann distribution to explain the significance of activation energy

3 explain qualitatively, in terms both of the Boltzmann distribution and of frequency of effective collisions, the effect of temperature change on the rate of a reaction

8.3 Homogeneous and heterogeneous catalysts

Learning outcomes

Candidates should be able to:

1 explain and use the terms catalyst and catalysis

(a) explain that, in the presence of a catalyst, a reaction has a different mechanism, i.e. one of lower activation energy

(b) explain this catalytic effect in terms of the Boltzmann distribution

(c) construct and interpret a reaction pathway diagram, for a reaction in the presence and absence of an effective catalyst

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1 Calcium, magnesium and radium are Group 2 elements. Radium follows the same trends as the other members of Group 2.

(g) Cold water reacts slowly with a piece of Mg to produce bubbles of $H_2(g)$.
Cold water reacts rapidly with burning Mg to produce $H_2(g)$ in an explosive mixture.

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

Explain why the rate of reaction of cold water with burning magnesium is greater.

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..... [2]

[Total: 17]

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2 Some oxides of elements in Period 3 are shown.

Na_2O Al_2O_3 P_4O_6 P_4O_{10} SO_2 SO_3

(b)

(iii) Al_2O_3 is used as a catalyst in the dehydration of alcohols.

State the effect of using Al_2O_3 as a catalyst in the dehydration of alcohols. Use the Boltzmann distribution in Fig. 2.1 to help explain your answer.

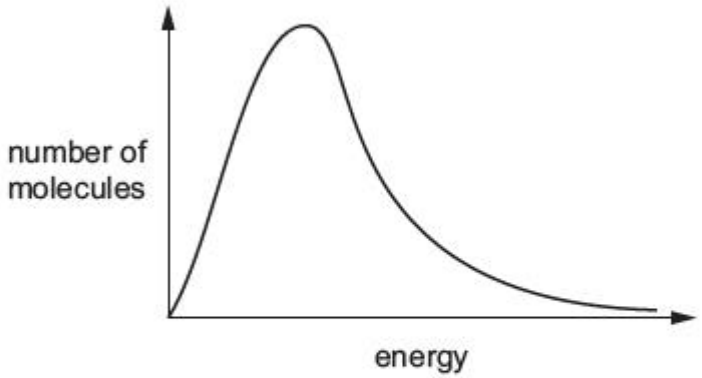

Fig. 2.1

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..... [3]

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(iv) H_2SO_4 acts as a homogeneous catalyst in reaction 3.

Explain why H_2SO_4 is described as *homogeneous*.

.....

..... [1]

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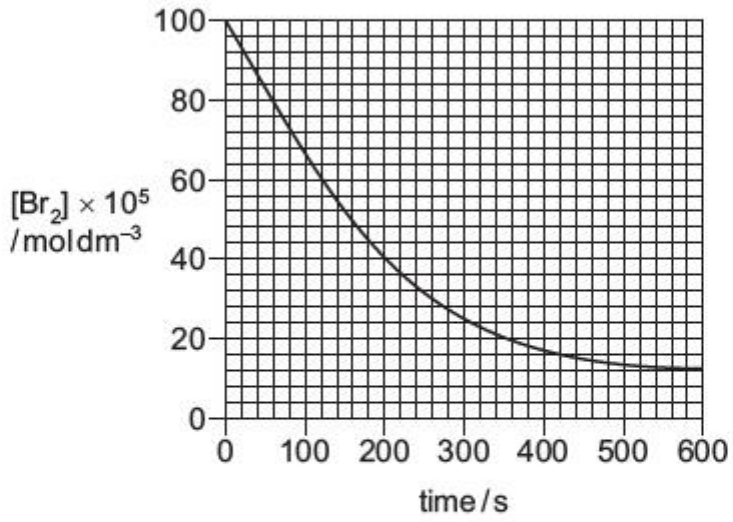
4 Aqueous bromine reacts with methanoic acid to form hydrogen bromide and carbon dioxide gas.

$$Br_2(aq) + HCO_2H(aq) \rightarrow 2HBr(aq) + CO_2(g)$$

(c) This reaction can be followed by measuring the concentration of bromine present in the mixture at regular time intervals.

The graph shows the change in concentration of bromine against time in a reaction carried out at 20 °C.



(i) Use the graph to calculate the average rate of reaction at 20 °C during the first 600 s. State the units of this rate of reaction.

average rate of reaction ..... units .....

[2]

The experiment is repeated at a temperature of 40 °C. This relatively small increase in temperature produces a large increase in reaction rate.

(ii) Sketch a graph, on the same axes, to show the expected results when repeating the experiment at 40 °C. [1]

(iii) The rate of reaction increases when the frequency of successful collisions between reactant particles increases.

Explain why an increase in temperature produces this effect.

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..... [2]

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1 The rate of chemical reactions is affected by changes in temperature and pressure.

(a) (i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.

[2]

(ii) On the diagram in **(a)(i)**, draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**. [1]

(b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

(i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1 .....

.....

2 .....

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[2]

(ii) Explain, in terms of activation energy, E_a, and the collision of particles, how an increase in temperature affects the rate of a chemical reaction.

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..... [2]

Q# 174/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

(e) Lucas's reagent is a mixture of HC*l* and $ZnCl_2$. Primary, secondary and tertiary alcohols can be distinguished by their reaction with Lucas's reagent.

Alcohols react with the HC*l* in Lucas's reagent to form halogenoalkanes.

$ZnCl_2$ acts as a homogeneous catalyst for these reactions.

(i) Explain the meaning of the term *homogeneous*.

.....

..... [1]

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3 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example $CHCl_3$.

(ii) An important reaction of $CHCl_3(g)$ is the manufacture of $CHClF_2(g)$, using the following reversible reaction.

$$CHCl_3(g) + 2HF(g) \rightleftharpoons CHClF_2(g) + 2HCl(g)$$

(iii) The reaction in **(ii)** is carried out using a heterogeneous catalyst.

Explain fully the meaning of the terms *heterogeneous* and *catalyst*.

heterogeneous .....

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catalyst .....

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[3]

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1 Sulfuric acid is manufactured by the Contact process.

One stage in this process is the conversion of sulfur dioxide into sulfur trioxide in the presence of a heterogeneous catalyst of vanadium(V) oxide, V_2O_5.

$$2O{=}S{=}O(g) + O{=}O(g) \rightleftharpoons 2O{=}\overset{\overset{O}{\|}}{S}{=}O(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) (i) State the effect of a catalyst on a reaction.
Explain how a catalyst causes this effect.

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..... [2]

(ii) State the meaning of the term *heterogeneous* as applied to catalysts.

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..... [1]

1 Ammonia, NH_3, is manufactured from nitrogen and hydrogen by the Haber process.

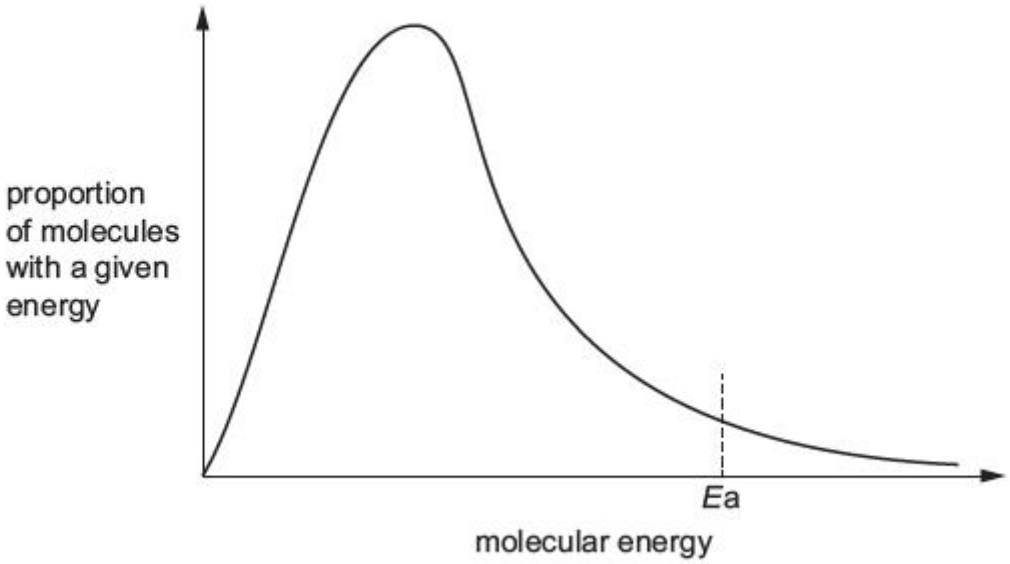
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Some bond energies are given.

$N \equiv N = 944\,kJ\,mol^{-1}$
$H–H = 436\,kJ\,mol^{-1}$

(b) The Haber process is usually carried out at a temperature of approximately 400 °C in the presence of a catalyst. Changing the temperature affects both the rate of production of ammonia and the yield of ammonia.

The Boltzmann distribution for a mixture of nitrogen and hydrogen at 400 °C is shown.
*E*a represents the activation energy for the reaction.



(i) Using the same axes, sketch a second curve to indicate the Boltzmann distribution at a higher temperature. [2]

(ii) **With reference to the Boltzmann distribution**, state and explain the effect of increasing temperature on the rate of production of ammonia.

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..... [3]

(c) Hydrogen chloride undergoes a reversible reaction with oxygen.

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

The reaction is carried out at 400 °C in the presence of a copper(II) chloride catalyst.

(ii) State the **type** of catalyst used in this reaction. Explain how a catalyst is able to increase the rate of a chemical reaction.

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..... [2]

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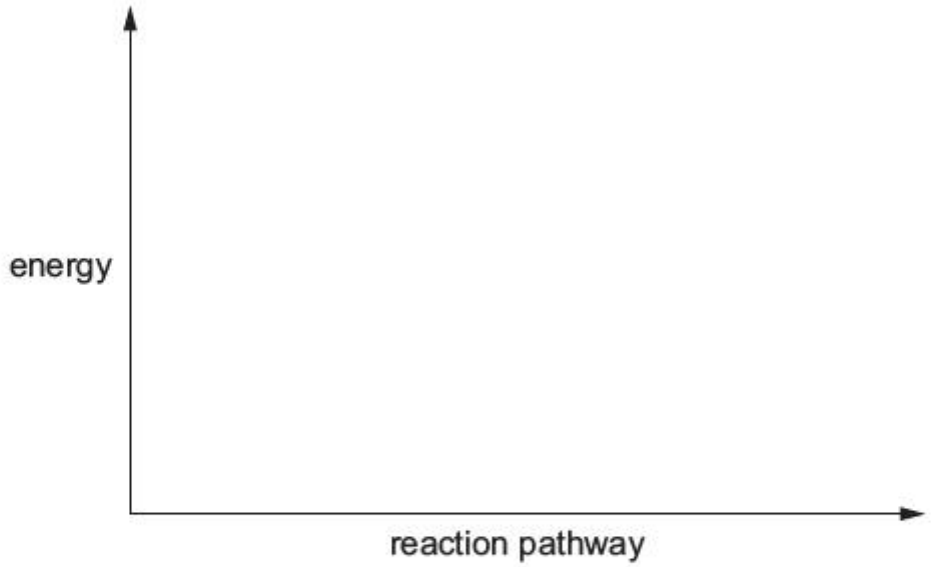
(b) Magnesium oxide can be formed by the reaction of magnesium and oxygen in the air.

(i) Draw a **fully labelled** reaction pathway diagram for the reaction between magnesium and oxygen.



[2]

(ii) Explain why there is no visible reaction when a piece of magnesium ribbon is exposed to the air.

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..... [2]

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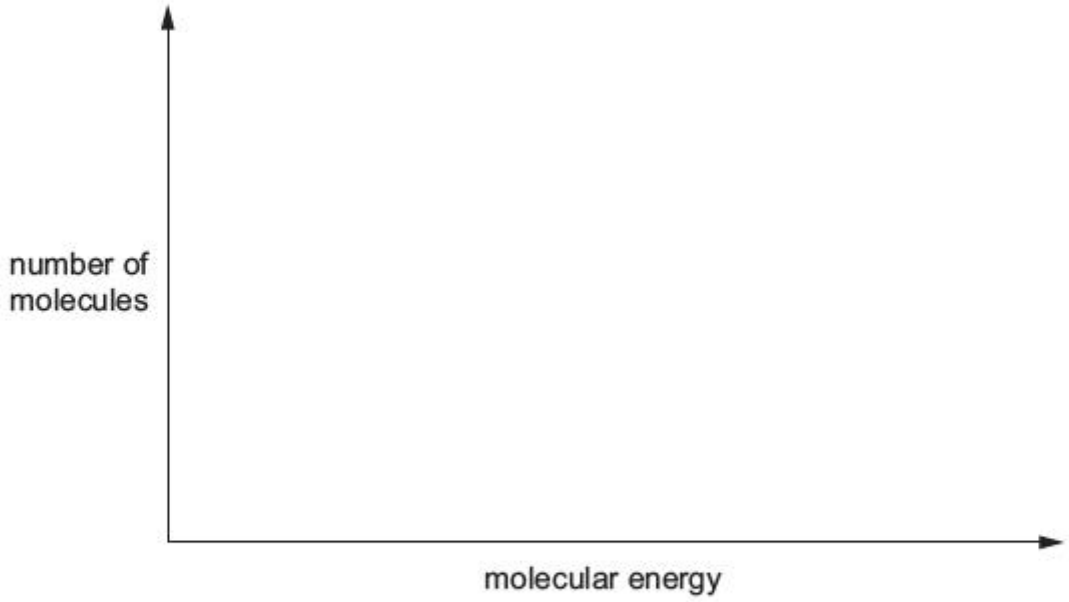
3 Over one million tonnes of hydrogen cyanide, HCN, are produced each year using the Andrussow process. The overall equation for the reaction is shown.

$$CH_4(g) + NH_3(g) + 1\tfrac{1}{2}O_2(g) \rightleftharpoons HCN(g) + 3H_2O(g)$$

(c) The process uses a platinum catalyst, which increases the rate of reaction.

Sketch a Boltzmann distribution on the axes given below and use your diagram to explain how the platinum catalyst increases the rate of the reaction.



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..... [3]

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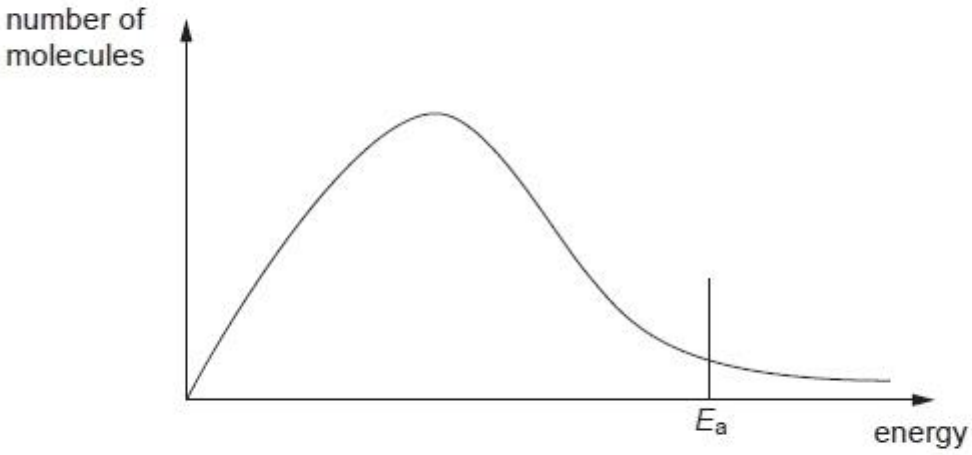
2 The diagram below shows, for a given temperature T, a Boltzmann distribution of the kinetic energy of the molecules of a mixture of two gases that will react together, such as nitrogen and hydrogen.
The activation energy for the reaction, E_a, is marked.



(a) On the graph above,

(i) draw a new distribution curve, **clearly labelled T′**, for the same mixture of gases at a higher temperature, **T′**;

(ii) **mark clearly, as H**, the position of the activation energy of the reaction at the higher temperature, **T′**.

[3]

(b) Explain the meaning of the term *activation energy*.

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..... [2]

The reaction between nitrogen and hydrogen to produce ammonia in the Haber process is an example of a large-scale gaseous reaction that is catalysed.

(ii) **On the energy axis of the graph opposite**, mark the position, **clearly labelled C**, of the activation energy of the reaction when a catalyst is used.

(iii) Use your answer to **(ii)** to explain how the use of a catalyst results in reactions occurring at a faster rate.

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..... [2]

(d) Two reactions involving aqueous NaOH are given below.

$CH_3CHBrCH_3 + NaOH \rightarrow CH_3CH(OH)CH_3 + NaBr$ **reaction 1**

$HCl + NaOH \rightarrow NaCl + H_2O$ **reaction 2**

In order for **reaction 1** to occur, the reagents must be heated together for some time. On the other hand, **reaction 2** is almost instantaneous at room temperature.

Suggest brief explanations why the rates of these two reactions are very different.

reaction 1 .....

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.....

reaction 2 .....

.....

..... [4]

[Total: 12]

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1(g)	**M1** (heat / energy released from burning Mg) provides more particles with energy ⩾ E_a **M2** frequency of successful / effective collisions is greater	2

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2(b)(iii)	two lines shown on diagram, *e.g.* E_A and $E_{A,cat}$ [1] greater proportion of molecules with $E \geqslant E_A$ [1] frequency of effective collisions increases [1]	3

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4(a)(iv)	in the same phase / in same state	1

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4(c)(i)	rate = total change in concentration of Br_2 divided by time taken *calculation dependent on graph* *$(100 \times 10^{-6} - 12 \times 10^{-6}) / 600$* **M1** average rate of reaction 1.47×10^{-6}	1
	M2 units mol dm^{-3} s^{-1}	1
4(c)(ii)	graph shown on same axes has steeper initial gradient AND reaches the same final [Br_2]	1
4(c)(iii)	**M1** (at increased temp the average kinetic) energy of particles / species / molecules increases.	1
	M2 (many) more/greater proportion of particles with energy ⩾ E_a	1

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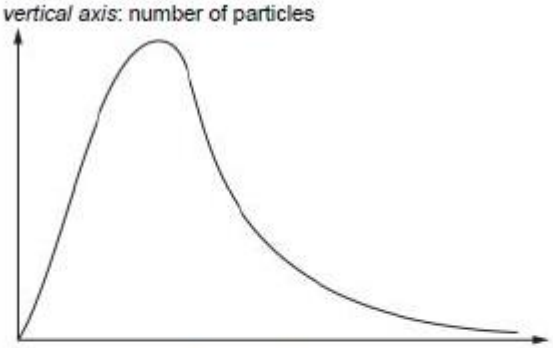
1(a)(i)	*vertical axis*: number of particles  *horizontal axis:* (kinetic / particle) energy **M1:** shape of curve correct **M2:** labelled axes	2
1(a)(ii)	Labelled line (**T2**) with lower peak to right of original	1
1(b)(i)	Any two from: • no VdW forces present / no forces of attraction between particles • (ideal gas) particles have no / negligible volume (compared to container) • collisions between (ideal gas) particles / walls of container are perfectly elastic • (ideal gas) particles behave as rigid spheres	2
1(c)(ii)	• rate increases • (increase in temperature means) more particles have energy ⩾ activation energy • frequency of successful collisions increases	2

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2(e)(i)	in the same phase / state	1

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3(a)(iii)	**M1** in a different phase / state from reactants **M2** a substance that speeds up a (chemical) reaction **M3** catalyst is regenerated / not used up / undergoes temporary chemical change / recovered unchanged	3

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1(a)(i)	(It is a substance that) speeds up a reaction	1
	(by creating an alternative pathway / mechanism with) lower E_a	1
1(a)(ii)	(a heterogeneous catalyst is in a) different state / phase (to the reactants)	1

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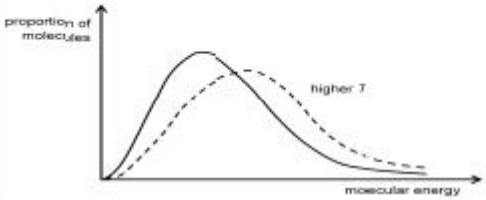
1(b)(i)	general shape of the curve and peak are displaced to right of original line and starts at origin	1
	the peak is lower and curve crosses once only finishing above original line	1
		
1(b)(ii)	rate increases AND explanation in terms of collisions	1
	(at higher T) area above E_a is greater OR (at higher T) more molecules with $E \geqslant E_a$	1
	higher frequency of successful collisions OR more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1

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2(c)(ii)	heterogeneous (catalyst)	1
	provides an alternative reaction pathway of lower activation energy	1

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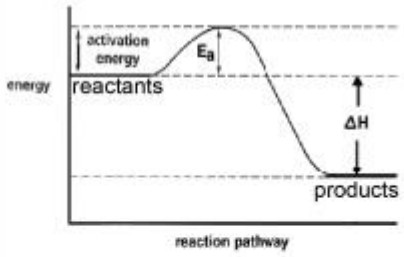
(b) (i)	 M1 – general layout with products below reactants AND both labelled M2 – E_a and ΔH/ energy change /released labelled with vertical lines	[1] [1]	[2]
(ii)	activation energy is high so few/no particles with $E \geqslant E_a$	[1] [1]	[2]

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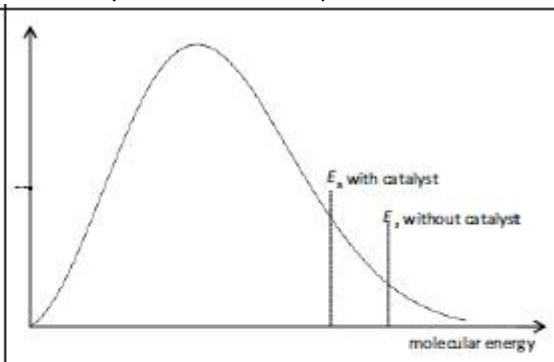
(c)



[3]

M1 = correct Boltzmann curve [1]

M2, M3 any 2 from: [1] [1]
- line for **both** E_a values or statement in text that catalyst lowers E_a
- (catalyst) increases proportion/number of molecules/particles with energy ≥ activation energy
- so more frequent successful collisions

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2 (a) (i) new graph has **lower** maximum (1)
maximum is **to the right of** previous maximum (1)

(ii) **H** is at E_a (1) [3]

(b) the minimum amount of energy molecules must have **or** energy required (1)
in order for the reaction to take place (1) [2]

(ii) **C** is placed to the left of **H** (1)

(iii) more molecules now have energy $>E_a$ (1) [4]

(d) **reaction 1**
has greater E_a (1)
because energy is needed to break covalent bonds (1)
reaction 2
has lower E_a
or actual reaction is $H^+ + OH^- \rightarrow H_2O$
or reaction involves ions (1)
opposite charges attract (1) [4]

[Total: max 12]