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VCE Chemistry ¾
Rates of Reaction [0.17]
Workshop

Error Logbook:

New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
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Section A: Recap

Learning Objective: [2.6.1] – Explain how factors increase the frequency of collisions

Concentration	Pressure
Used for [aqueous (aq)] / [gaseous (g)] mixtures.	Used for [aqueous (aq)] / [gaseous (g)] mixtures.

- To increase the frequency of **successful** collisions with **correct orientation**, the frequency _____ collisions must be [increased] / [decreased].
- **Concentration/Pressure** can be **increased** by:

Amount (n)	Volume (V)
[increase] / [decrease] amount of particles.	[increase] / [decrease] volume of container.

- **Increase in Concentration or Pressure**
  - When concentration/pressure is increased, **particles move**: [closer together] / [further apart]
  - **Frequency of total collisions:** [increases] / [decreases]
  - **Frequency** of **fruitful/successful collisions** with **correct orientation** collisions: [increases] / [decreases]
  - **Overall rate of reaction:** [increases] / [decreases]
- Increase in Concentration or Pressure Flow Chart

Key Feature →_____ Freq. Collisions

→ Frequency of _____ Collisions with Correct Orientation

→ Rate of Reaction

Effect of Inert Gas on Rate of Reaction

- When an inert gas is added, the **overall pressure:** [increases] / [decreases] / [stays same]
- Partial pressure of reactants: [increases] / [decreases] / [stays same]
- Frequency of collisions between reactants: [increases] / [decreases] / [stays same]
- Rate of reaction: [increases] / [decreases] / [stays same]

Surface Area

- Cutting/dividing substance into thin powder [increases] / [decreases] surface area.
- **Contact between reactants:** [increases] / [decreases]
- **Total frequency of collisions:** [increases] / [decreases]
- **Frequency** of **fruitful/successful collisions** with **correct orientation** collisions: [increases] / [decreases]
- **Overall rate of reaction:** [increases] / [decreases]

Space for Personal Notes

Learning Objective: [2.6.2] – Explain how temperature & catalyst affect the proportion of successful collisions

- Greatest effect on the rate of reaction: [frequency of collisions] / [energy upon collision]
- **Effect of Temperature on Rate (Sample Response)**
  - **Overall**: Increasing temperature [increases] / [decreases] average kinetic energy.

Energy Upon Collision	Frequency of Collision
Reacting particles collide with [greater] / [lesser] force.	Average moving speed of particles: [increases] / [decreases] / [same]
Probability of colliding with sufficient energy to overcome the activation energy [increases] / [decreases] / [same]	Total frequency of collisions: [increases] / [decreases] / [same]
Proportion/probability of successful/fruitful collisions [increases] / [decreases] / [same]	Frequency of successful collisions: [increases] / [decreases] / [same]

- Energy Upon Collision Flow Chart:

_____ Energy → Greater _____ → Greater _____ for Collisions with _____ _____ → Greater Rate

- **Catalysts are** substances that _____ the rate of a chemical reaction without itself being _____.
- Catalysts alter the rate of reaction by providing an _____ reaction pathway with a _____ activation energy.

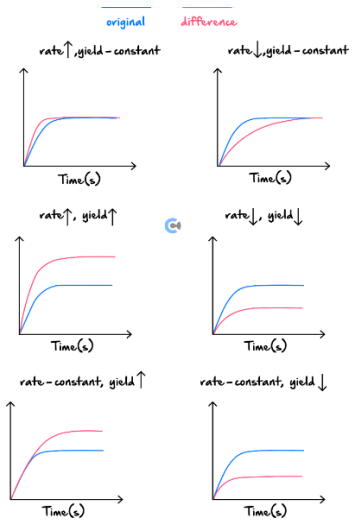
- Catalyst Sample Response:
  - A catalyst provides an alternative reaction pathway with lower activation energy by forming **temporary** and **partial intermolecular bonds** with the reacting particles.
  - **Activation Energy:** [increases] / [decreases] / [stays same]
  - **Rate of Reaction:** [increases] / [decreases] / [stays same]
- Catalyst Before vs After: _____.

Definition

Learning Objective: [2.6.3] - Graph differences in rate & yield

Method of Measuring Rate	Conditions
Change in Volume (Gas Syringe)	Gaseous Products
Change in Mass (Weighing Scale)	Gaseous Products
Change in pH (pH meter/indicator)	H^+ or OH^- used/formed
Change in Temperature (Thermometer)	Reaction is endothermic/exothermic

- **Rate vs Yield in Graphs**



Section B: Warm Up (16 Marks)

INSTRUCTION: 16 Marks. 10 Minutes Writing.

Question 1 (1 mark)

Write the three requirements for a chemical reaction to occur below.

1. _____

2. _____

3. _____

Question 2 (3 marks)

For each of the following, state how the proposed change influences the rate of reaction.

a. Using powdered magnesium instead of a strip of magnesium. (0.5 marks)

[increases] / [decreases] / [same] rate

b. Injecting helium into a gaseous reaction vessel. (0.5 marks)

[increases] / [decreases] / [same] rate

c. Using 2.0 *M* HCl instead of 1.0 *M* HCl. (0.5 marks)

[increases] / [decreases] / [same] rate

d. Adding a material to the reaction vessel lowers the reaction's activation energy. (0.5 marks)

[increases] / [decreases] / [same] rate

e. Lowering the temperature of the system. (0.5 marks)

[increases] / [decreases] / [same] rate

f. Reacting $H_2(g)$ and $O_2(g)$ in a 100 *L* tank instead of a 10 *L* tank. (0.5 marks)

[increases] / [decreases] / [same] rate

Space for Personal Notes

Question 3 (4 marks)

a. Explain, using collision theory, how increasing the temperature at which a reaction takes place increases the rate of reaction occurring. (3 marks)

_____

_____

_____

_____

_____

_____

b. Outline the major difference between this method of increasing the rate of reaction compared to all other methods of speeding up a reaction. (1 mark)

_____

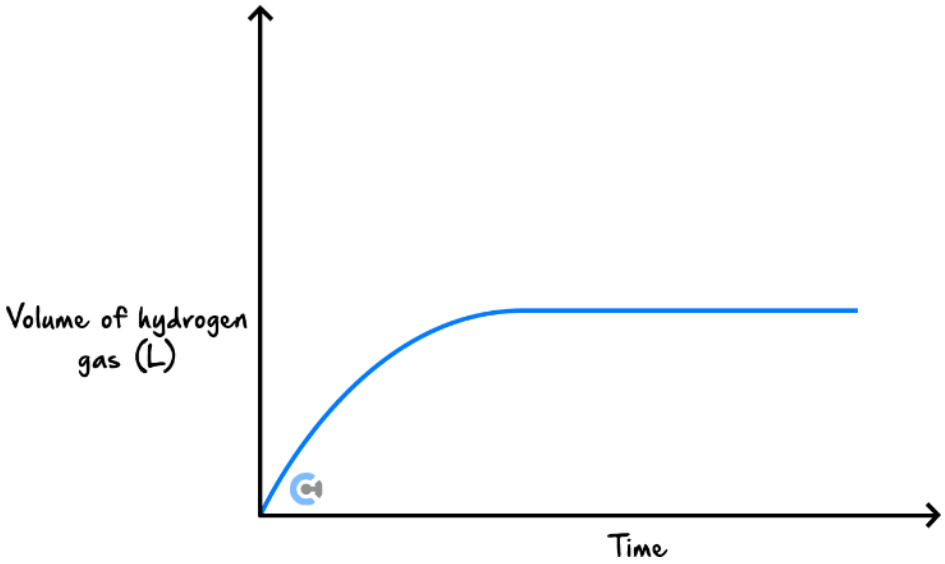
_____

Space for Personal Notes

Question 4 (4 marks)

A 2.0 g piece of magnesium ribbon was added to a known volume of 2.0 M hydrochloric acid. The volume of hydrogen gas produced during the reaction was measured and recorded.

The graph below shows the result of this experiment.



a. Write an equation for the reaction between magnesium and hydrochloric acid. (2 marks)

_____

_____

b. In a second experiment, 2.0 g of magnesium **powder** was added to the same volume of 2.0 M hydrochloric acid as used in the first experiment.

On the axes above, sketch the expected graph of the volume of hydrogen against time for this second experiment. Give an explanation for the shape of your graph. (2 marks)

_____

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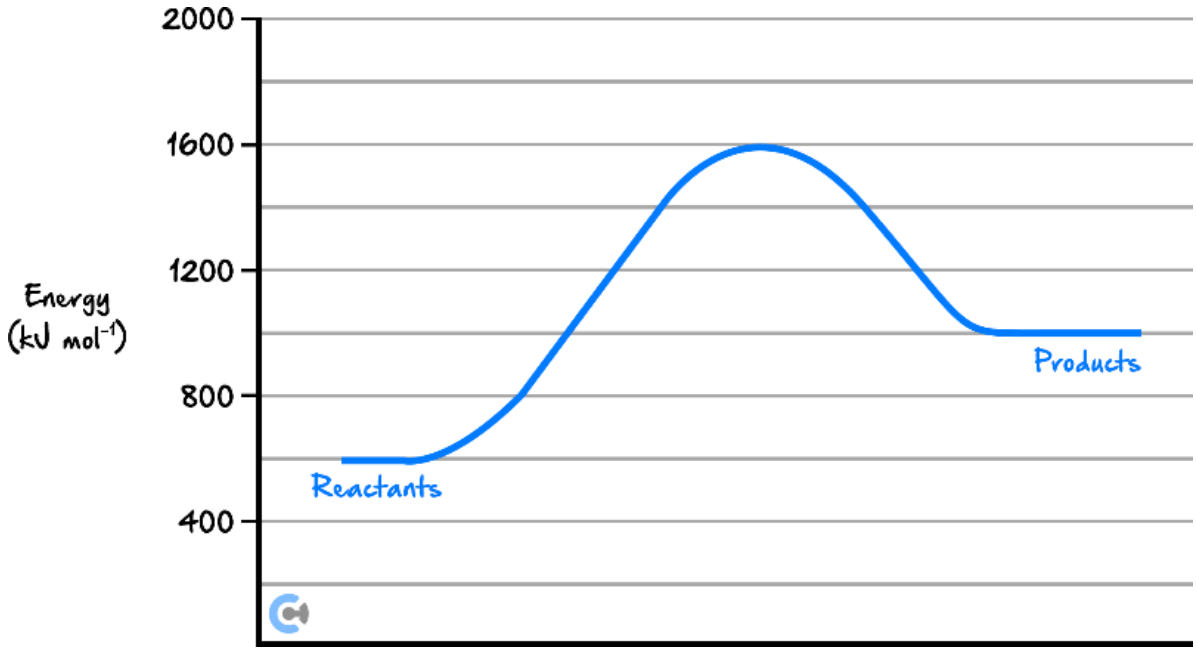
Question 5 (2 marks)

The following diagram shows the energy profile for a reaction.



A catalyst reduces the activation energy by 250 $kJ\ mol^{-1}$.

Find the value of the activation energy and enthalpy change with a catalyst.

Activation Energy ($kJ\ mol^{-1}$)	**Enthalpy Change ($kJ\ mol^{-1}$)**

Question 6 (2 marks)

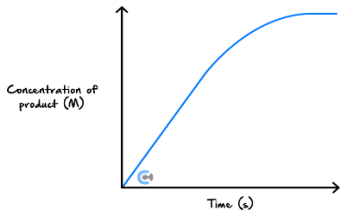
Explain the effect of dipping 50.0 g of cobalt metal into 5 mL of 1.0 M HCl compared to 10 mL of 1.0 M HCl.

Section C: Ramping Up (11 Marks)

INSTRUCTION: 11 Marks. 9 Minutes Writing.

Question 7 (1 mark)

A student conducted an experiment to determine the rate of a chemical reaction. The graph of the student's results is shown below.



Which one of the following correctly shows the units of the initial rate of reaction?

A. $mol\ L^{-1}\ S^{-1}$

B. $mol\ L^{-1}$

C. $mol\ S^{-1}$

D. mol

Question 8 (1 mark)

The two statements below give possible explanations for changes that occur when the temperature of a reaction mixture is increased.

I. At a higher temperature, particles move faster and the reactant particles collide more frequently.

II. At a higher temperature, more particles have energy greater than the activation energy.

Which alternative below best explains why the observed reaction rate is greater at higher temperatures?

A. I only.

B. II only.

C. I and II to an equal extent.

D. I and II, but II to a greater extent than I.

Question 9 (1 mark)

Some carbon dioxide is to be generated by reacting 50 g of calcium carbonate with a solution of hydrochloric acid. Which of the following actions is the least likely to lead to an increase in the rate of formation of carbon dioxide?

A. Grinding the calcium carbonate to a fine powder.

B. Raising the temperature.

C. Raising the atmospheric pressure.

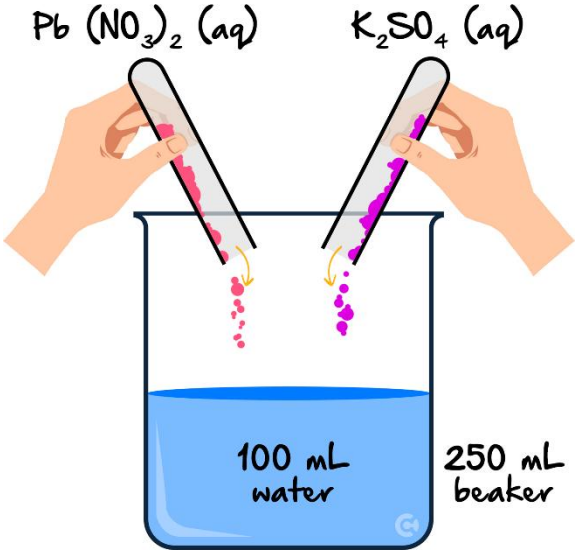
D. Raising the concentration of hydrochloric acid.

Space for Personal Notes

Question 10 (8 marks)

Claire is studying the reaction that occurs between **1.0** ***M*** lead (II) nitrate and **1.0** ***M*** potassium sulfate in a 250 mL beaker containing 100 mL of water according to the reaction:

$$Pb(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow 2KNO_3(aq) + PbSO_4(s)$$

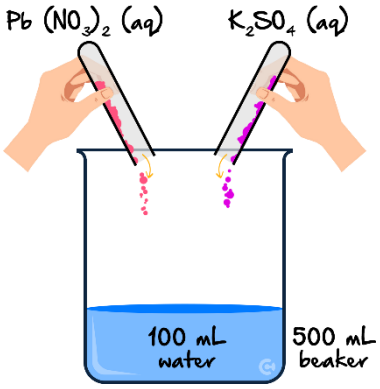


Explain what effect each of the following would have on the rate of reaction observed **when compared** to the original set-up shown above.

a. Using 2.0 *M* solutions. (2 marks)

b.

i. The same reaction took place with the same chemicals and concentrations $(1.0\ M)$, but this time, the volume was increased. The vessel is now a $500\ mL$ beaker still containing $100\ mL$ of water. Explain the effect this has on the rate of reaction. (2 marks)



_____

_____

_____

_____

ii. In the $500\ mL$ beaker set-up shown above, a lid is now placed and the pressure is increased. Explain the effect this has on the rate of reaction. (2 marks)

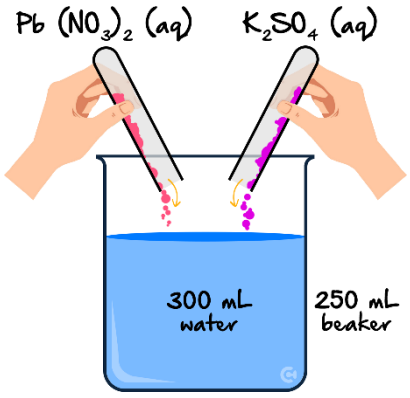
_____

_____

_____

_____

iii. The experiment is then reverted back to the original 1.0 M concentration solutions and the 250 mL beaker, but once the reactants are mixed together, water is added to the solution, almost completely filling the beaker. (2 marks)



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Section D: Getting Trickier I (15 Marks)

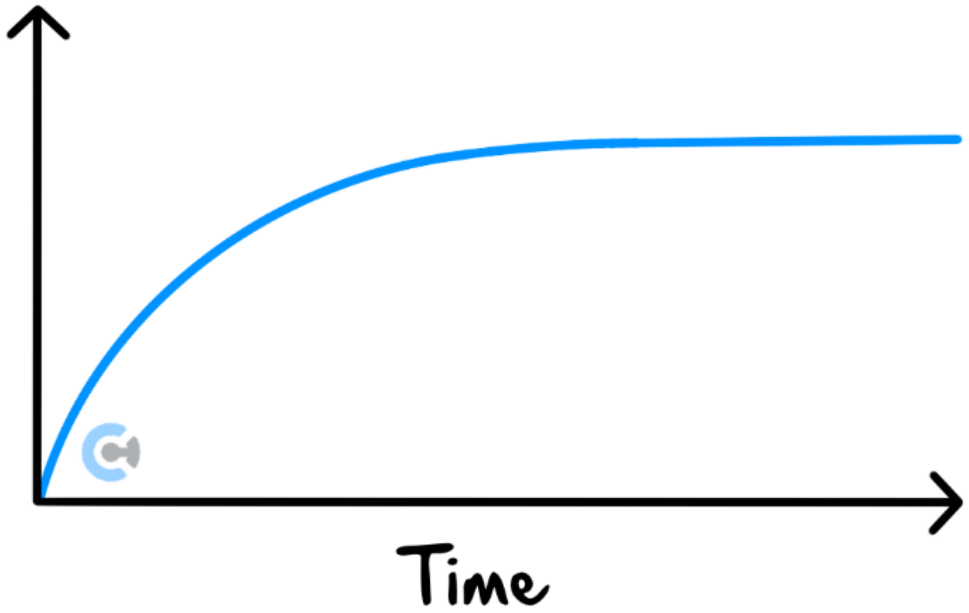
INSTRUCTION: 15 Marks. 12 Minutes Writing.

Question 11 (1 mark)

The reaction between zinc and hydrochloric acid may be represented by the equation:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g); \qquad \Delta H = -154\ kJ\ mol^{-1}$$

In an investigation of this reaction using excess Zn and 2 M HCl(aq) in an open flask, the following graph was plotted from the data collected.



Which of the following would be a suitable quantity for the vertical axis of the graph?

A. Number of collisions per second.

B. Rate of reaction.

C. Temperature.

D. Number of ions.

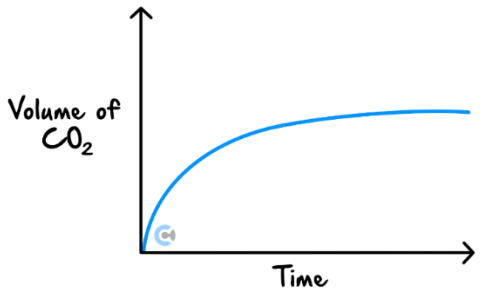
Space for Personal Notes

Question 12 (1 mark)

The reaction between excess calcium carbonate and hydrochloric acid can be followed by plotting a graph of the total volume of carbon dioxide produced against time. The reaction occurs according to the equation:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A plot of $V(CO_2)$ versus time for the reaction is shown below.



This graph is consistent with the observation that:

A. The rate of reaction increases with time because the surface area of the $CaCO_3$ increases.

B. The rate of reaction increases with time because the acid becomes more dilute.

C. The rate of reaction decreases with time because the surface area of the $CaCO_3$ increases.

D. The rate of reaction decreases with time because the acid becomes more dilute.

Question 13 (1 mark)

Consider the following features of a chemical reaction.

I. Activation energy.

II. ΔH of the reaction.

III. Enthalpy of the reactants.

Compared with the uncatalysed reaction pathway, the presence of a catalyst changes.

A. I only.

B. II only.

C. II and III only.

D. I, II and III.

Question 14 (12 marks)

The Haber process involves the reaction between nitrogen and hydrogen to produce ammonia.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \ \Delta H = -92.4\ kJ$$

a.

i. Oftentimes, a piece of platinum is added to the reaction vessel. Explain the purpose of adding platinum. (1 mark)

_____

ii. Suppose a 10 g strip of platinum is placed initially into the reaction vessel. Once the reaction is completed, explain any physical changes to this platinum strip. (1 mark)

_____

_____

b.

i. Given that the effect of adding platinum is that the activation energy of the **reverse** reaction is lowered by 120 kJ**,** compare this to the effect it would have on the activation energy for the **forward** reaction.
(1 mark)

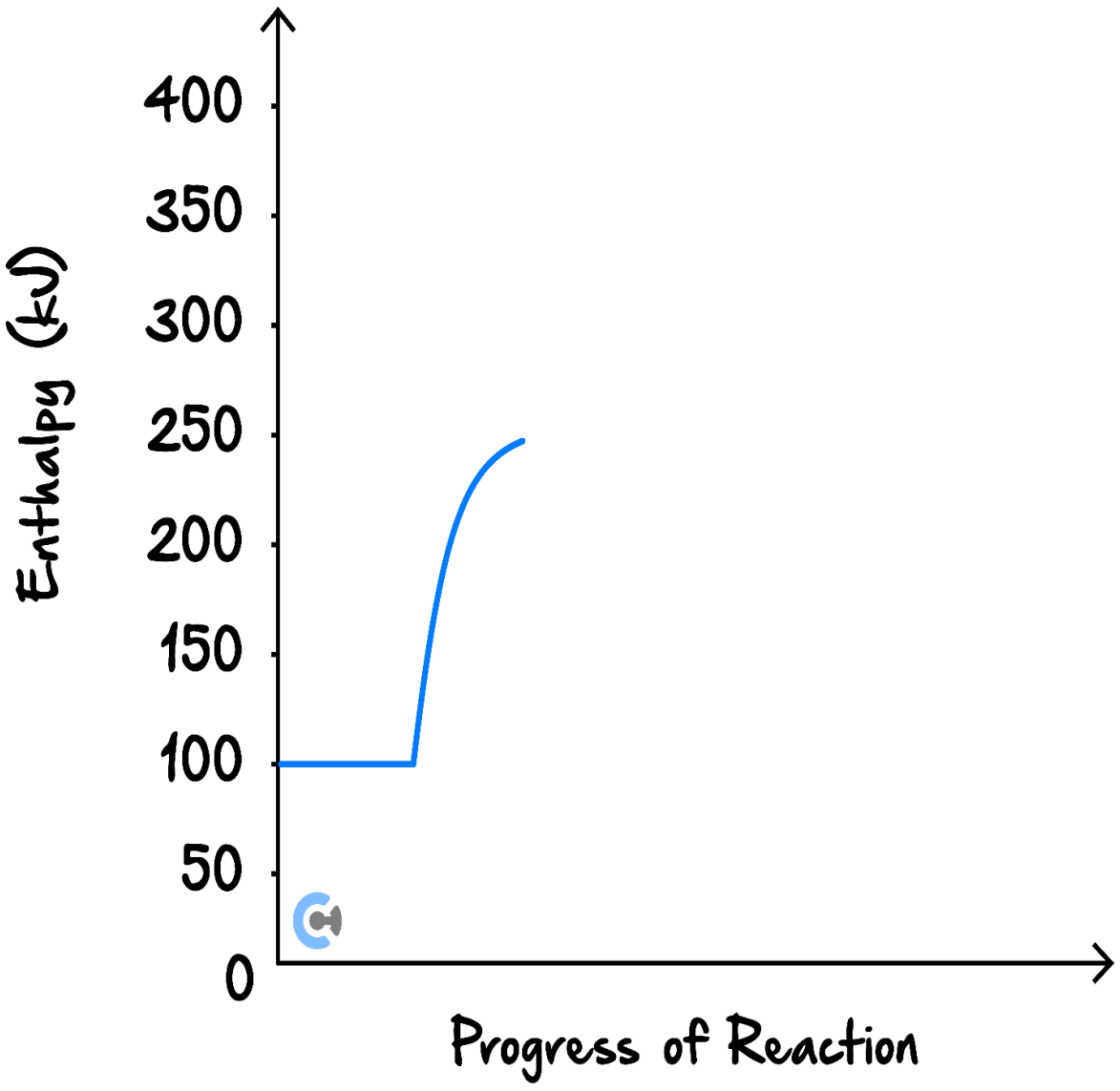
_____

_____

ii. Hence, or otherwise, on the set of axes below, complete the energy profile diagram for **both** the **forwards** uncatalysed **and** catalysed reactions.

*The partial curve shown represents **part** of the energy profile diagram for the **forward, catalysed** reaction.*
(3 marks)

Ensure to label each curve as catalysed or uncatalysed, as well as their E_a and ΔH values.



c.

i. Explain, using collision theory, how the platinum strip affects the rate of ammonia production. (2 marks)

_____

_____

_____

_____

ii. John tells you that the frequency of successful collisions is increased by the addition of the platinum strip because the frequency of total collisions has increased.

Evaluate John's statement, giving clear reasons for your answer. (2 marks)

_____

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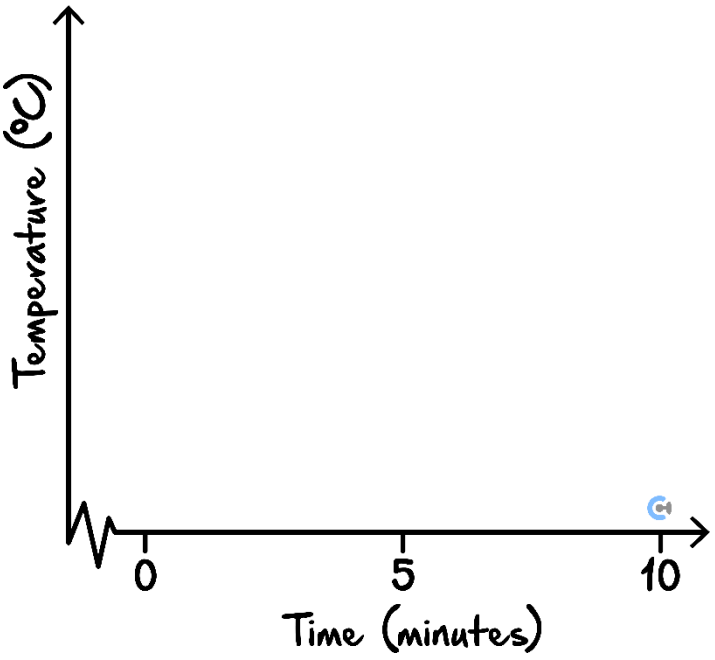
_____

d. Draw the graph to show how the temperature **of the reaction vessel** (which is not perfectly insulated) changes over the course of 10 minutes on the set of axes below. Assume the reaction takes 5 minutes to take place. (2 marks)



Section E: Getting Trickier II (6 Marks)

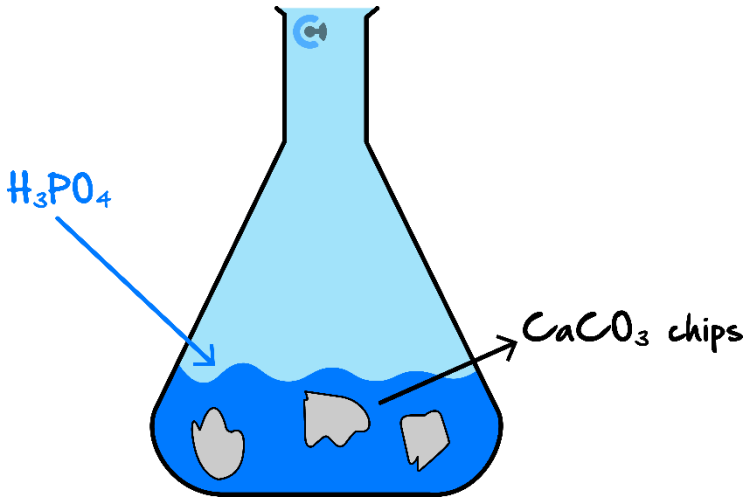
INSTRUCTION: 6 Marks. 3 Minutes Writing.

Question 15 (6 marks)

Curtis is exploring how to graph different chemical and physical changes as the following reaction takes place:

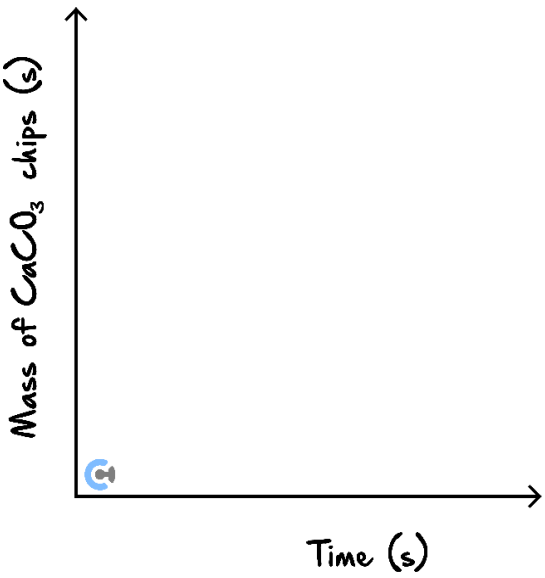
$$2H_3PO_4(aq) + 3CaCO_3(s) \rightarrow Ca_3(PO_4)_2(aq) + 3H_2O(l) + 3CO_2(g)$$

His set-up is depicted below:

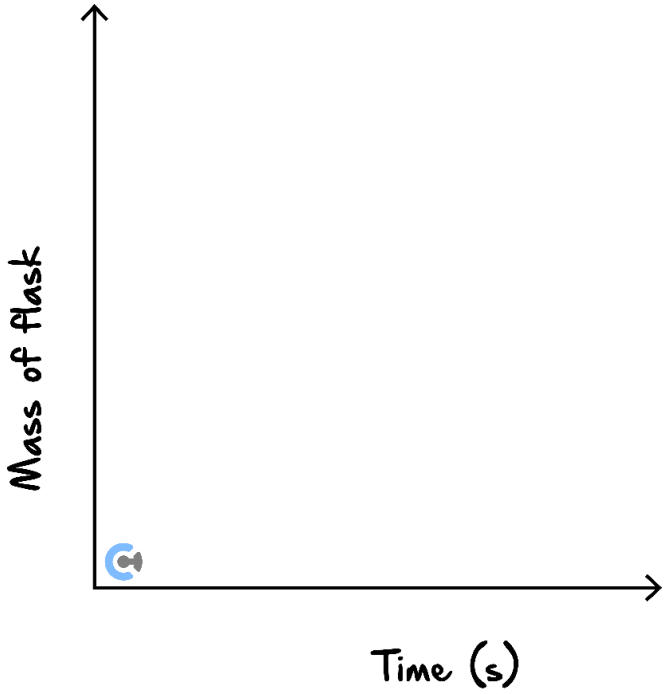


a. Draw the following curves according to the labels on each set of axes below. Assume an excess of phosphoric acid, unless otherwise specified. (3 marks)

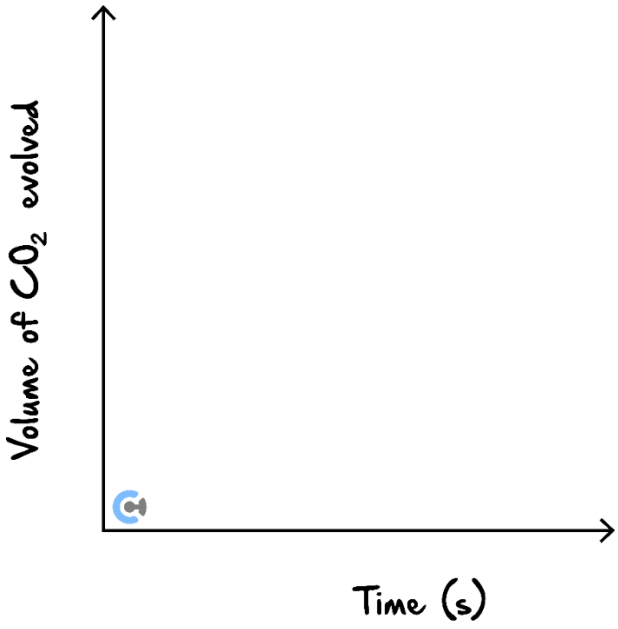
i.



ii.



iii.



b. On the same set of axes for **parts a. i.-iii.,** draw another curve which represents the effect of using granular marble chips as opposed to large ones. (3 marks)

Let's take a BREAK!

Section F: VCAA-Level Questions I (12 Marks)

INSTRUCTION: 12 Marks. 30 Seconds Reading. 12 Minutes Writing.

Question 16 (7 marks)

Inspired from VCAA Chemistry Exam 2004
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/chem12004.pdf#page=9

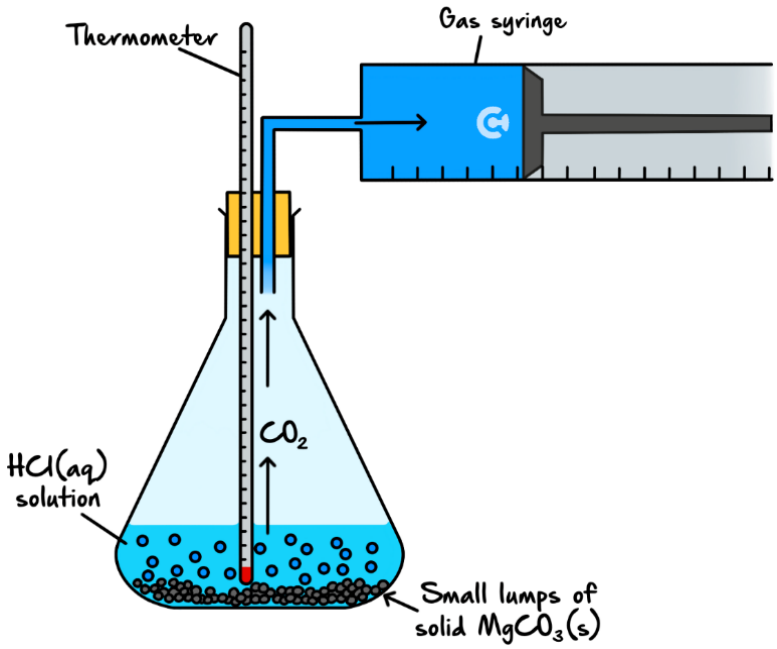
The main source of the element magnesium in Australia is the ore magnesite, in which magnesium is present as magnesium carbonate ($MgCO_3$).

a. Calculate the percentage by mass of magnesium in magnesium carbonate. (1 mark)

b. Magnesium carbonate reacts with aqueous hydrochloric acid according to the reaction:

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

A series of laboratory experiments was set up to study the rate of this reaction under different conditions. The initial reaction rate was determined by measuring the rate of evolution of CO_2 in a gas syringe as shown in the following diagram.



Four experiments were carried out as follows. **In each case, the amount of HCl present was in excess.**

Experiment	**[HCl] (M)**	**Mass of $MgCO_3(g)$**	**Initial temp in °C**	**Final temp in °C**	**Initial rate of CO_2 evolution in $mL\ min^{-1}$**
1	0.10	1.0	20	25	5
2	0.10	1.0	30	35	50
3	0.10	2.0	20	30	10
4	0.20	1.0	20	25	20

i. Is the reaction exothermic or endothermic? Explain how you can tell from these results. (1 mark)

_____

_____

_____

ii. Considering experiments 1 and 2, explain why the increase in the initial temperature has raised the reaction rate. (1 mark)

_____

_____

_____

iii. Considering experiments 1 and 3, explain why the greater mass of magnesium carbonate would have increased the reaction rate. (1 mark)

_____

_____

_____

iv. Considering experiments 1 and 4, explain why the higher concentration of HCl would have increased the reaction rate. (1 mark)

_____

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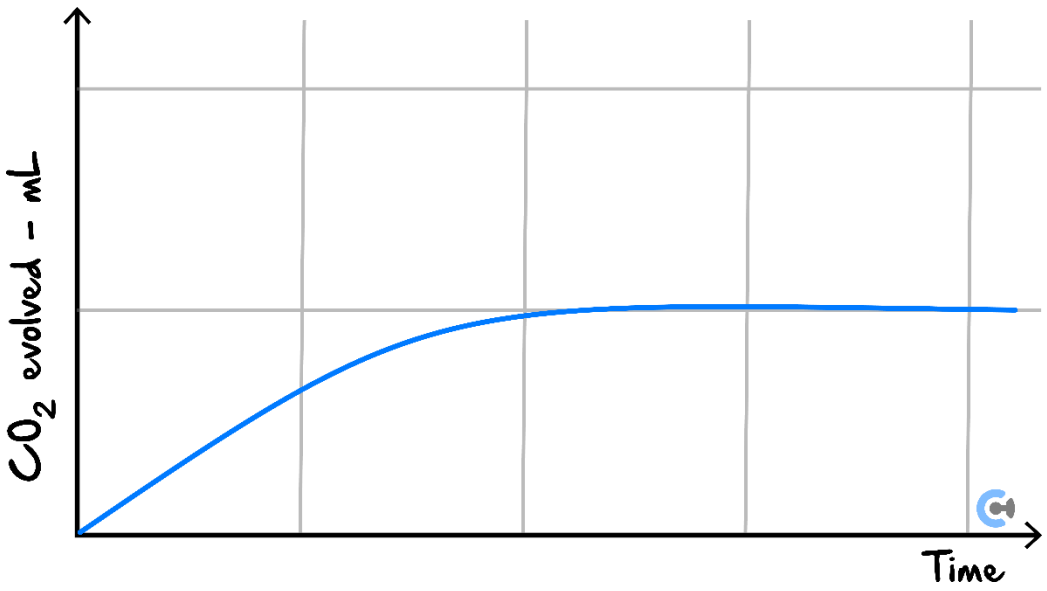
_____

v. Results from experiment 1 are plotted on the sketch graph below. On the same axes, sketch the results from the experiment 3. (2 marks)



Question 17 (5 marks)

Inspired from VCAA Chemistry Exam 2019
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2014/2014chem-amd-w.pdf#page=16

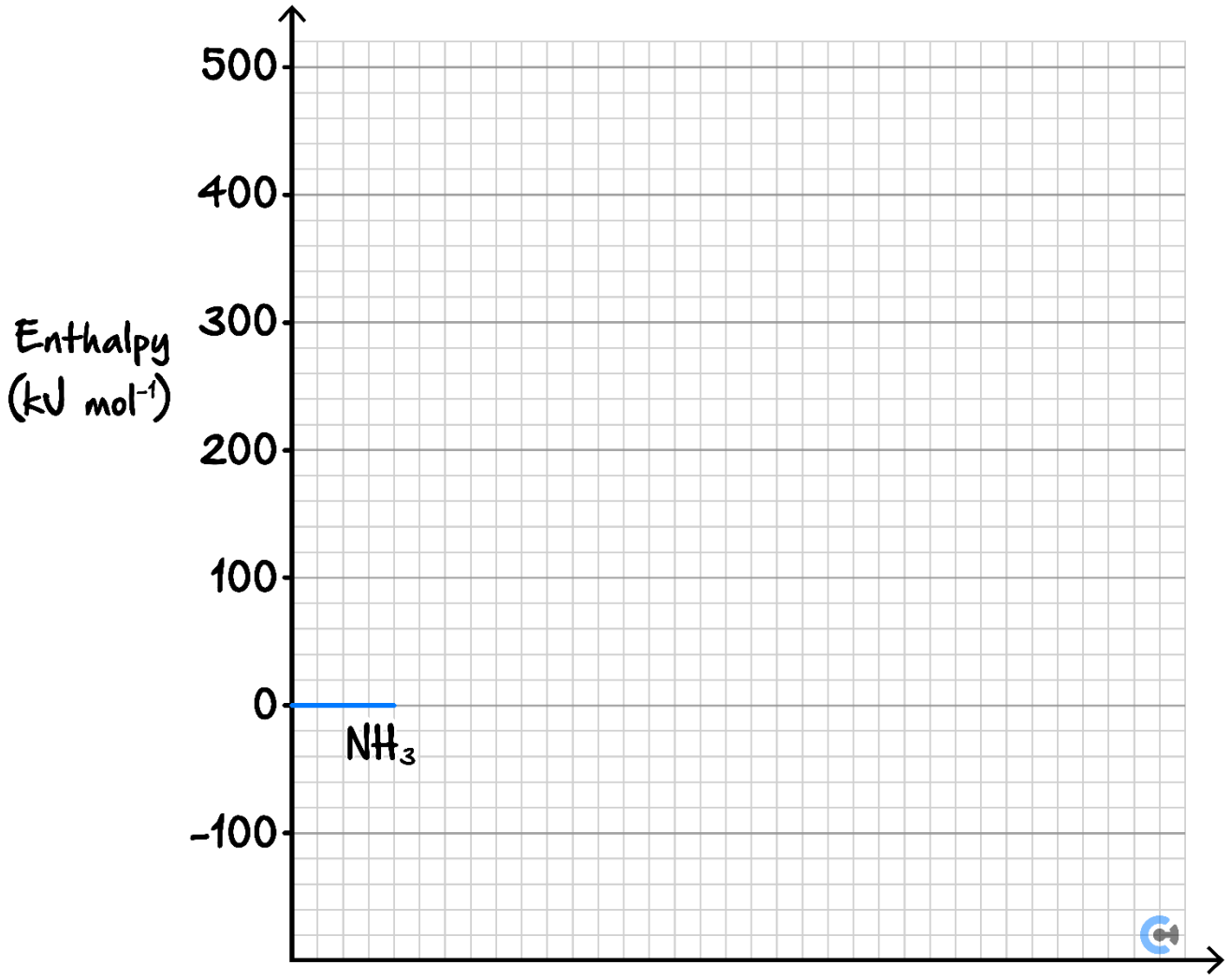
The decomposition of ammonia is represented by the following equation:

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g) \;\; \Delta H = +92.4\, kJ/mol$$

a. The activation energy for the uncatalysed reaction is 335 $kJ\ mol^{-1}$.

The activation energy for the reaction when tungsten is used as a catalyst is 163 $kJ\ mol^{-1}$.

On the grid provided below, draw a labelled energy profile diagram for the uncatalysed and catalysed reactions. (3 marks)



b. When osmium is used as a catalyst, the activation energy is 197 $kJ\ mol^{-1}$.

Which catalyst, osmium or tungsten, will cause ammonia to decompose at a faster rate? Justify your answer in terms of the chemical principles you have studied this year. (2 marks)

_____

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Space for Personal Notes

Section G: Multiple Choice Questions (9 Marks)

INSTRUCTION: 9 Marks. 9 Minutes Writing.

Question 18 (1 mark)

Pieces of polished magnesium, Mg(s), are added to 100 mL of 1.0 M hydrochloric acid, HCl(aq), and react according to the equation below:

$$Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

Which one of the following is most likely to decrease the rate of the reaction?

A. Use 100 mL of 2.0 M HCl.

B. Use Mg powder instead of Mg pieces.

C. Warm the 100 mL of 1.0 M HCl before using it.

D. Use unpolished Mg pieces instead of polished Mg pieces.

Question 19 (1 mark)

The rate of a reaction between two gases increases when the temperature is increased and a catalyst is added. Which statements are both correct for the effect of these changes?

	Increasing temperature	Adding a catalyst
A.	Collision frequency increases	Activation energy increases
B.	Activation energy increases	Activation energy does not change
C.	Activation energy does not change	Activation energy decreases
D.	Activation energy stays constant	Collision frequency increases

Space for Personal Notes

Question 20 (1 mark)

For the reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \qquad \Delta H = -92.3\ kJ\ mol^{-1}$$

A. A catalyst increases the number of collisions between the reactants.

B. The rate of the forward reaction increases when the temperature increases.

C. A catalyst reduces the activation energy of the forward and backward reactions by the same proportion.

D. The activation energy of the forward reaction is greater than the activation energy of the reverse reaction.

Question 21 (1 mark)

Inspired From VCAA Chemistry Exam 2016
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2016/2016chem-amd-w.pdf#page=12

A class of Chemistry students investigated the reaction of Copper metal and Iodine solution. After making predictions about the reaction, they placed a Copper strip into an Iodine solution and compared their predictions with their observations. A number of groups recorded the following.

Reactants	Prediction	Observation over 10 minutes
Cu metal + I_2 solution	A reaction should occur. The expected products are Cu^{2+} and I^-. The solution should turn from brown to blue as I_2 is consumed and Cu^{2+} is formed. The Cu metal should look corroded.	No apparent change

The predicted results were not observed. The class was asked to suggest some hypotheses to explain the unexpected result.

Which one of the following hypotheses could **not** explain the unexpected result?

A. The reaction rate might have been too slow for the time allowed.

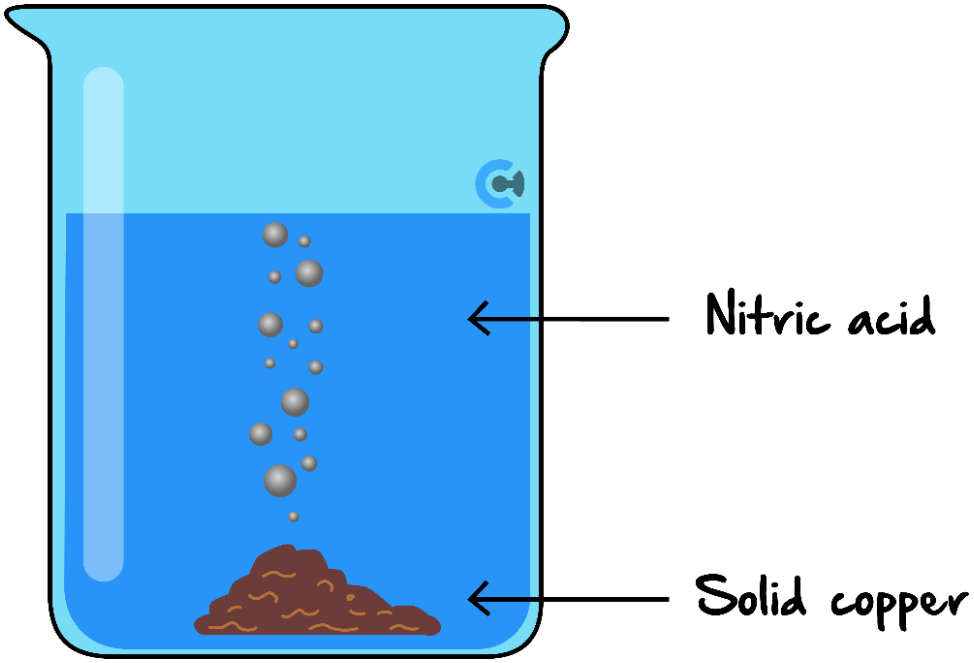
B. An equilibrium was established and $[Cu^{2+}]$ was too low to be visible.

C. A bromine solution was accidentally used in place of the Iodine solution.

D. The surface of the copper metal was greasy.

The following information applies to the two questions that follow.

$$Cu(s) + 4HNO_3\,(aq) \rightarrow Cu(NO_3)_2\,(aq) + 2NO_2\,(g) + 2H_2O(l)$$



Question 22 (1 mark)

Which one of the following will **not** increase the rate of the above reaction?

A. Decreasing the size of the solid Copper particles.

B. Increasing the temperature of HNO_3 by 20°C.

C. Increasing the concentration of HNO_3.

D. Allowing NO_2 gas to escape.

Question 23 (1 mark)

In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions.

The **major** reason for this is that:

A. The nitric acid is ionised in solution.

B. Some reactant particles have too much kinetic energy.

C. The kinetic energy of the particles is reduced when they collide with the container's walls.

D. Not all reactant particles have the minimum kinetic energy required to initiate the reaction.

The following information applies to the two questions that follow.

The equation for the reaction of nickel metal with dilute hydrochloric acid can be written as:

$$Ni(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + H_2(g) \qquad \Delta H = -ve$$

Question 24 (1 mark)

Compared with carrying out the reaction at 25°C using 1 *M* HCl(aq), which one of the following condition changes would yield a slower rate of Hydrogen gas evolution?

A. Adding a catalyst to the reaction mixture.

B. Adding 1 *M* Sulfuric acid to replace the Hydrochloric acid.

C. Cooling the mixture to 10°C.

D. Heating the mixture to 30°C.

Question 25 (1 mark)

Which of the following would cause an increased rate of the Nickel dissolving?

A. Decreasing the temperature at which the reaction was carried out.

B. Using an acidic solution with a higher pH.

C. Adding some potassium chloride to the reaction mixture.

D. Adding the same mass of nickel but using smaller strips of nickel.

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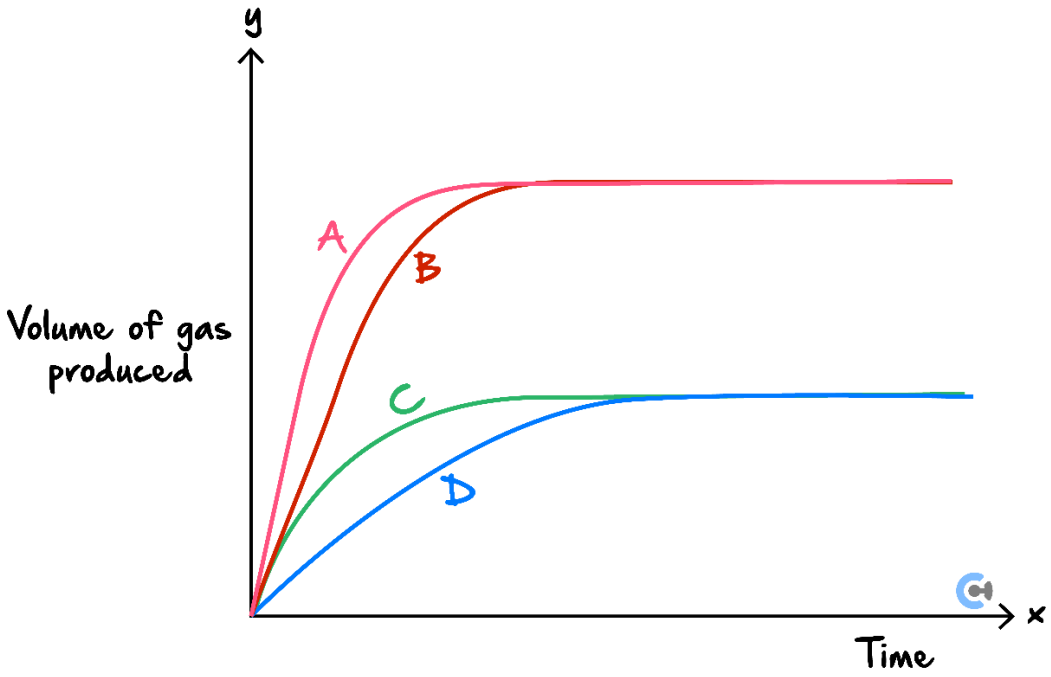
Question 26 (1 mark)

Magnesium carbonate reacts with dilute nitric acid according to the equation:

$$MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(aq) + CO_2(g)$$

In an experiment to investigate the effect of different conditions on the rate of reaction between excess solid magnesium carbonate and 200 mL of nitric acid, the gas produced in the reaction is collected in a gas syringe and volume collected plotted against time for four different sets of reaction conditions.

The resulting graphs are shown below.



Which of the following statements is **not** consistent with the recorded data?

A. The size of $MgCO_3$ particles were not the same in all four investigations.

B. The concentration of HNO_3 was the same in all four investigations.

C. A catalyst may have been used in one or more of the investigations.

D. The initial temperature may not have been consistent across all four investigations.

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Section H: VCAA-Level Questions II (6 Marks)

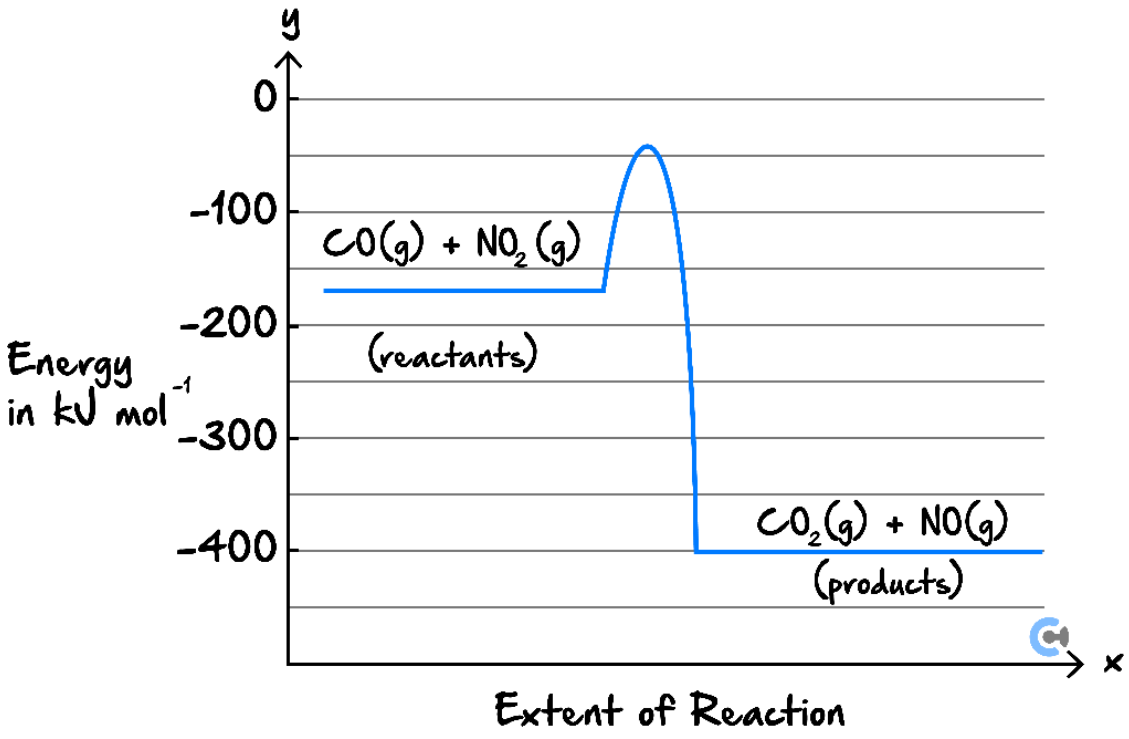
INSTRUCTION: 6 Marks. 30 Seconds Reading. 6 Minutes Writing.

Question 27 (6 marks)

Inspired from VCAA Chemistry Exam 2019
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/05chem1.pdf#page=16

The graph below represents the energy changes over the course of a chemical reaction.

$$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$$



a. Give the magnitude and sign of the ΔH for the forward reaction in $kJ\ mol^{-1}$. (1 mark)

b. Give the activation energy for the reverse reaction in $kJ\ mol^{-1}$. (1 mark)

c. Give two reasons explaining why the rate of this reaction increases with increasing temperature. (2 marks)

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d. A suitable catalyst is discovered for the reaction. What would be the likely effect of the catalyst on:

i. The activation energy? Explain your answer. (1 mark)

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ii. The ΔH? Explain your answer. (1 mark)

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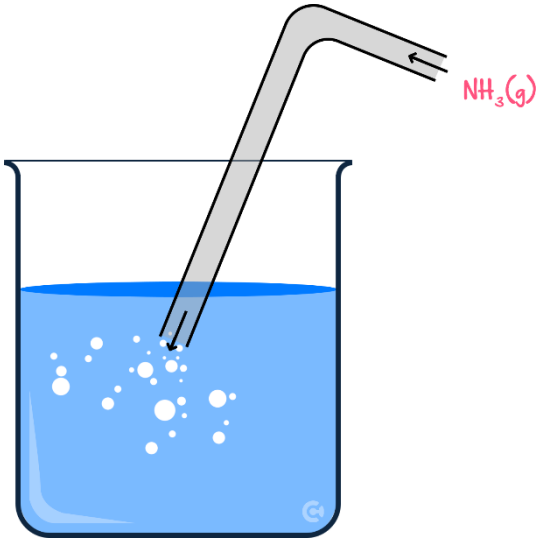
Section I: Extension Questions (9 Marks)

Question 28 (9 marks)

Krishna is bubbling a finite amount of ammonia gas into a beaker containing water, as shown below:



a. Write the reaction occurring when ammonia gas is dissolved in water. (1 mark)

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b. Outline how the rate of dissolution would differ if a smaller beaker was used (containing the same volume of water). (2 marks)

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c. If more water were added to the beaker, explain the impact it would have on the rate of dissolution. (2 marks)

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d.

i. If the pressure of the ammonia gas inputted were to be increased, explain what impact this would have on the rate of dissolution. (2 marks)

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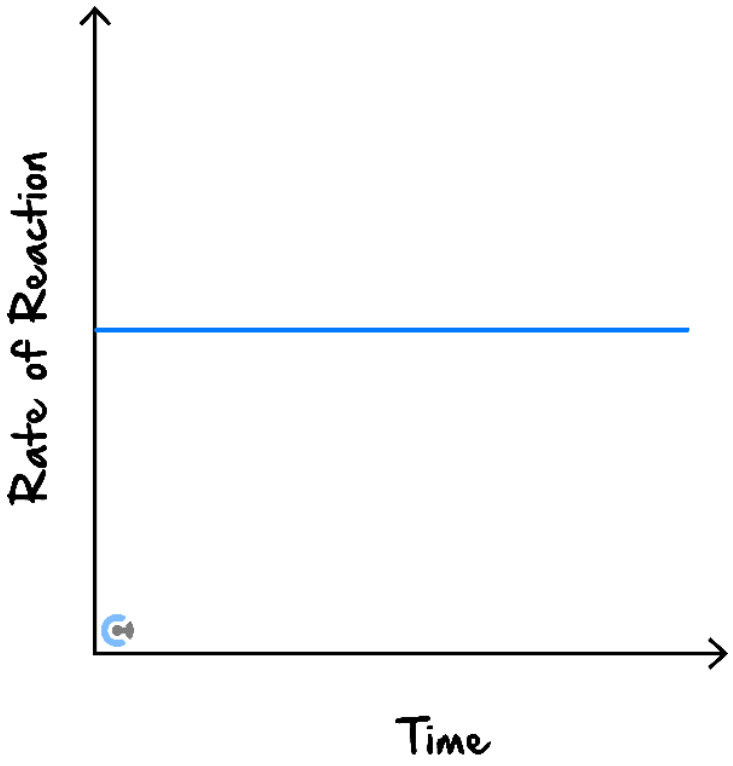
ii. On the graph below, draw the effect of **pressurised ammonia** being pumped in compared to the dissolution of ammonia stored at 100 kPa (shown below) **and explain** why the shape of the graph shown is linear. (2 marks)



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