KINETICS STUDY GUIDE- *Written*

Written Section: What follows is a comprehensive guide to the written component of the Chemistry 12 Provincial exam for the Kinetics Unit. The questions below are from previous provincial examinations from Jan'94 – Apr'00. For best results, go through each of these questions and check your answers against the "keys" provided. (The questions are in sequence for Jan'94)

INTRODUCTION

A3 1.

Consider the following reaction:

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

A 0.024 g sample of Mg reacts completely with HCl in 14.0 s. Calculate the average rate of consumption of HCl in mol/s. **(2 marks)**

A3 2. Consider the following reaction:

$$Cu_{(s)} + 2AgNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$$

In a rate experiment, a coil of copper wire is placed into a solution of silver nitrate. The following data are recorded.

Time (hours)	Mass of Copper (g)
0.0	3.45
4.0	2.12

Calculate the rate of this reaction. **(2 marks)**

A3 3. A strip of magnesium was cut into 4 pieces, each of length 1.0 cm and mass of 0.00864 g. Each piece was placed into a test tube containing 5.0 mL of different concentrations of HCl. The time required for each piece of magnesium to be completely consumed was recorded:

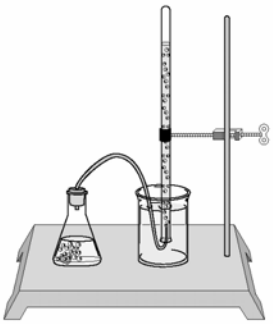
TRIAL	[HCl]	TIME (s)
1	0.50 M	200
2	1.0 M	38
3	3.0 M	12
4	6.0 M	6

a) Calculate the rate of reaction for magnesium in 3.0 M HCl. **(1 mark)**

b) How does the [HCl] affect the reaction rate? **(1 mark)**

A3 4. An experiment is performed by displacement of water to determine the rate of the following reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$$



The following data is collected:

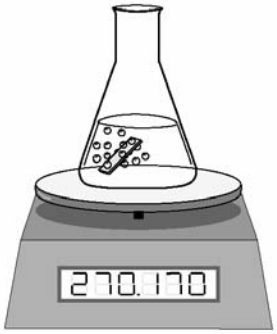
Time (s)	Volume of H_2 (mL)
0.0	0.0
10.0	21.1
20.0	40.9
30.0	60.0
40.0	77.6

a) Calculate the average rate of formation of H_2 in mL/s for the time interval between 20 and 40 seconds. **(2 marks)**

b) How does the rate of this reaction change as the reaction proceeds? Explain why. **(2 marks)**

A3 5. An experiment is done to determine the rate of the following reaction:

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 3H_{2(g)} + 2AlCl_{3(aq)}$$



The following data are collected:

TIME (s)	MASS OF FLASK PLUS CONTENTS (g)
0.0	270.230
30.0	270.200
60.0	270.170

Calculate the rate of consumption of Al in mol/min. **(3 marks)**

A4 6. A student wishes to monitor the rate of the following reaction:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(\ell)}$$

Identify **two** different properties that could be used to monitor the rate of the reaction. Describe and explain the changes that would occur. **(2 marks)**

Property 1: _____

Change and Explanation: _____

_____

Property 2: _____

Change and Explanation: _____

_____

A5 7. Carbon burns in air according to the following equation:

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

List **four** ways the rate of the above reaction could be increased. **(2 marks)**

A6 8. a) Define the term *heterogeneous reaction*. **(1mark)**
b) Give one example of a heterogeneous reaction. **(1mark)**

A6 9. Define and give an example of a *homogeneous* reaction. **(2marks)**

COLLISION THEORY

B1 10. Using collision theory, give **two** reasons why an increase in temperature results in an increase in reaction rate.

B1 11. State **two** reasons why some collisions may **not** result in a chemical reaction. **(2marks)**
Reason I: _____

_____

Reason II: _____

_____

B1 12. The combustion of coal, C, produces carbon dioxide gas according to the following equation:

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + 394\ kJ$$

a) What is the value of ΔH for this reaction? **(1 mark)**

b) Using collision theory, explain why a lump of coal does not react with oxygen at room temperature and pressure. **(1 mark)**

_____

_____

c) Many coal mine disasters have resulted when a spark ignites coal dust in the air. Explain, using collision theory. **(2 marks)**

_____

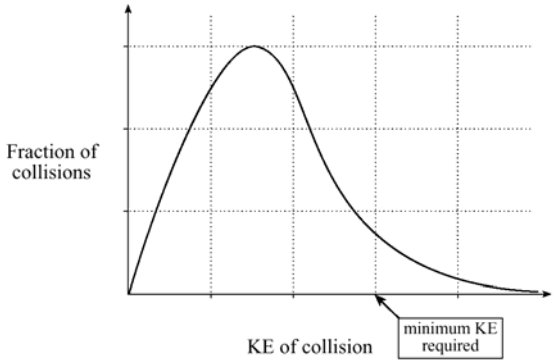
_____

_____

_____

B1 13. A reaction does not always occur when two reactant particles collide. Give **two** reasons why. **(2 marks)**

B1 14. Consider the following KE distribution curve for colliding particles:



a) On the diagram above, sketch a line for the distribution of collisions at a higher temperature. **(2 marks)**

b) Shade in the area representing the collisions that could result in forming an activated complex at the lower temperature. **(1 mark)**

B2 15. Define "activated complex." **(2 marks)**

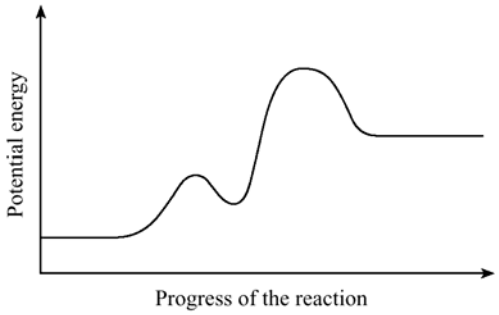
B2 16. Define the term *activated comple*x. **(2 marks)**

B3 17. What is *activation energy*?

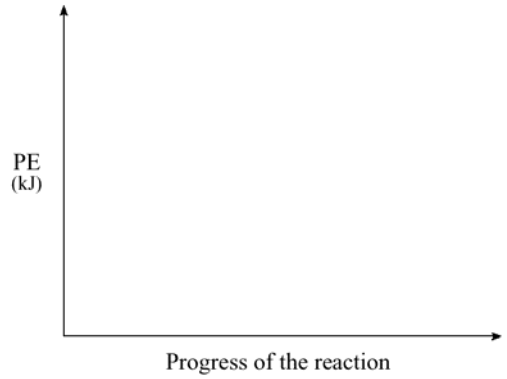
B4 18. Describe the relationship between activation energy and the rate of a chemical reaction. **(2 marks)**

B4 19. Using collision theory, explain why a mixture of natural gas and air does not react at room temperature but explodes when a piece of platinum is placed in the gas mixture. **(2 marks)**

B6 20. 1. a) On the potential energy diagram below, **clearly** label the
i) activation energy for the forward reaction. **(1 mark)**
ii) heat of reaction, ΔH. **(1 mark)**
iii) energy of the activated complex in the rate determining step. **(1 mark)**
b) Is the reaction endothermic or exothermic in the forward direction? **(1 mark)**



B6 21. a) On the graph below, draw the potential energy diagram for an exothermic reaction and label the activation energy. **(1mark)**

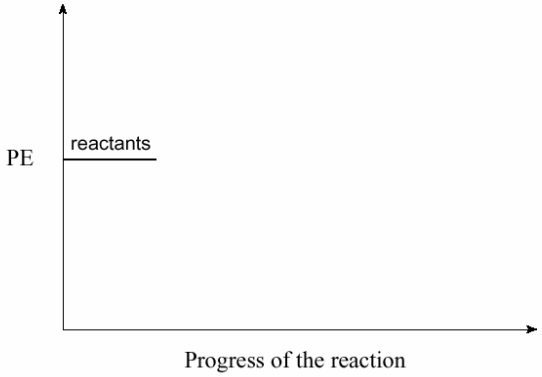


b) Define the term *activation energy*. **(1mark)**

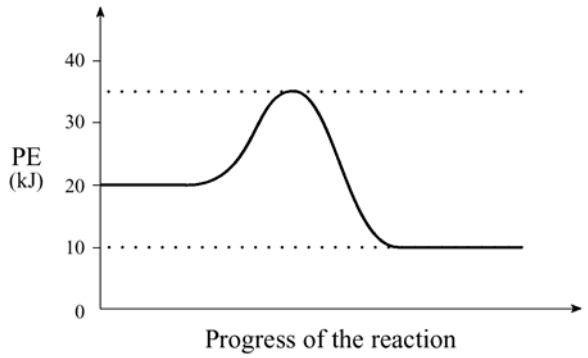
B6 22. Consider the following equilibrium:

$$CS_{2(g)} + 3Cl_{2(g)} \rightleftarrows CCl_{4(g)} + S_2Cl_{2(g)} \qquad \Delta H = -238 \text{ kJ}$$

a) Sketch a potential energy diagram for the reaction above and label ΔH.



B6 23. Consider the following potential energy diagram for a reversible reaction:



a) Calculate the activation energy for the forward reaction.

b) Calculate ΔH for the forward reaction.

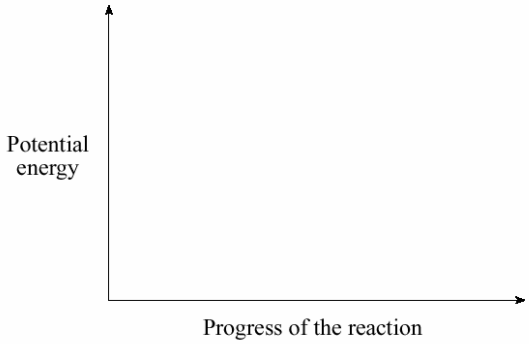
c) Calculate the activation energy for the reverse reaction.

d) On the diagram above, sketch a curve that could result when a catalyst is added.

B6 24. Sketch a potential energy diagram for an endothermic reaction in the space below.

On your diagram, label:

i) the energy of the activated complex
ii) the activation energy
iii) ΔH **(3 marks)**



B8 25. Consider the decomposition of ammonia:

$$2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$$

When 1.0 mol NH_3 reacts, 46 kJ of energy is absorbed. Rewrite the equation for this reaction, including the value of the heat term. **(1 mark)**

B9 26. Consider the following reaction:

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$

State one factor that would increase the rate of the above reaction. Use collision theory to explain the increase in rate. **(2marks)**

REACTION MECHANISMS AND CATALYSTS:

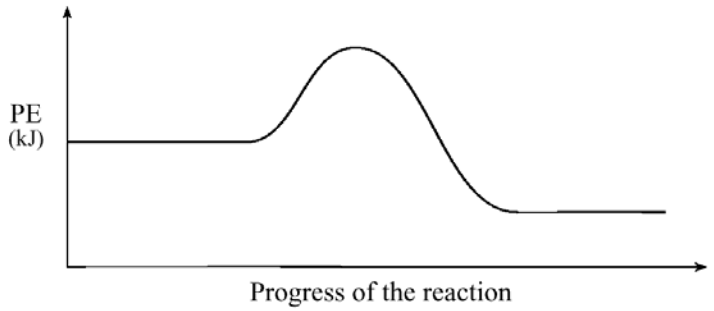
C2 27. Consider the following reaction:

$$4HBr_{(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} + 2Br_{2(g)}$$

Explain why the mechanism for the above reaction involves more than one step.
(1 mark)

C4 28. Consider the following PE diagram for the uncatalyzed decomposition of hydrogen peroxide:

$$2H_2O_{2(\ell)} \rightarrow 2H_2O_{(\ell)} + O_{2(g)}$$



a) On the PE diagram, sketch a curve for the catalyzed decomposition of H_2O_2.
(1 mark)

b) Compare the ΔH of the catalyzed and uncatalyzed reactions. **(1 mark)**

C5 29. Consider the following reaction for the formation of HCl in the presence of light.

$$Cl_2 + CHCl_3 \rightarrow HCl + CCl_4$$

The following is the proposed reaction mechanism:

Step 1	$Cl_2 \rightarrow Cl + Cl$
Step 2	**?**
Step 3	$Cl + CCl_3 \rightarrow CCl_4$

Determine Step 2 of the reaction mechanism. **(2 marks)**

C5 30. Consider the following overall reaction:

$$2NO + 2H_2 \rightarrow 2H_2O + N_2$$

a) Explain why the reaction is likely to involve more than one step. **(1 mark)**
b) A proposed mechanism for the reaction is:

Step 1: $NO + H_2 \rightarrow N + H_2O$
Step 2: ?
Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

i) Write the equation for Step 2. **(2 marks)**
ii) Identify all reaction intermediates. **(1 mark)**

C5 31. Nitric oxide (NO) is involved in the decomposition of ozone (O 3) by the following mechanism:

Step 1	$O_3 + \text{sunlight} \rightarrow O_2 + O$
Step 2	$O_3 + NO \rightarrow NO_2 + O_2$
Step 3	$NO_2 + O \rightarrow NO + O_2$

a) Write the net equation for the decomposition reaction. **(1 mark)**
b) Identify a catalyst. **(1 mark)**
c) Identify a reaction intermediate. **(1 mark)**
d)What is the function of sunlight in this reaction? **(1mark)**

C5 32. Consider the following reaction mechanism:

Step 1: $NO_{(g)} + O_{2(g)} \rightarrow NO_{3(g)}$
Step 2: $NO_{3(g)} + NO_{(g)} \rightarrow 2NO_{2(g)}$

a) Identify a reaction intermediate. **(1 mark)**

b) Write the equation for the overall reaction. **(1 mark)**

C5 33. Consider the following reaction mechanism:

Step 1: $ClO_{2(g)} + F_{2(g)} \rightarrow FClO_{2(g)} + F_{(g)}$ (slow)
Step 2: $F_{(g)} + ClO_{2(g)} \rightarrow FClO_{2(g)}$ (fast)

a) Write the equation for the overall reaction.

b) Identify a reaction intermediate.

C5 34. One of the reactions in the production of smog involves the oxidation of nitrogen monoxide. A possible mechanism for this reaction is:

Step 1: $CO + OH \rightarrow CO_2 + H$

Step 2: $H + O_2 \rightarrow HOO$

Step 3: $HOO + NO \rightarrow OH + NO_2$

a) Write the balanced equation for the overall reaction. **(2 marks)**

b) Identify all reaction intermediates. **(1 mark)**

c) Identify the catalyst. **(1 mark)**

C5 35. Consider the overall reaction:

$$4HBr_{(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} + 2Br_{2(g)}$$

A proposed three-step reaction mechanism is:

Step 1: $HBr + O_2 \rightarrow HOOBr$

Step 2: ?

Step 3: $HBr + HOBr \rightarrow H_2O + Br_2$

Write the equation for Step 2.

C5 36. Consider the following reaction mechanism:

Step 1: $NO + NO \rightarrow N_2O_2$

Step 2: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$

Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

a) Write the equation for the overall reaction.

b) Identify the reaction intermediate(s).

C5 37. Consider the following reaction mechanism:

Step 1	?
Step 2	$H_2 + Cl \rightarrow HCl + H$
Step 3	$H + Cl_2 \rightarrow HCl + Cl$
Step 4	$Cl + Cl \rightarrow Cl_2$
Overall	$H_2 + Cl_2 \rightarrow 2HCl$

a) Write the equation for Step 1. **(2 marks)**

b) Identify the reaction intermediate(s). **(1 mark)**

SOLUTION KEY:

1.

$$\text{mol Mg} = 0.024\,\text{g} \times \frac{1\,\text{mol}}{24.3\,\text{g}}$$

$$= 9.88 \times 10^{-4}\,\text{mol}$$

$$\text{mol HCl} = 2 \times \text{mol Mg}$$

$$= 2 \times \left(9.88 \times 10^{-4}\,\text{mol}\right)$$

$$= 1.98 \times 10^{-3}\,\text{mol}$$

← **1 mark**

$$\text{rate} = \frac{\text{mol HCl}}{\text{time}}$$

$$= \frac{1.98 \times 10^{-3}\,\text{mol}}{14.0\,\text{s}}$$

$$= 1.4 \times 10^{-4}\,\text{mol/s}$$

← **1 mark**

(Deduct $\frac{1}{2}$ **mark** for incorrect significant figures.)

2.

for a correct numerical answer. ← **1 $\frac{1}{2}$ marks**

for correct units. ← **$\frac{1}{2}$ mark**

e.g. 0.33 grams/hour

3. a) 0. 00864 g /12 s = 0. 00072 g/ s
   b) The higher the concentration of HCl, the faster the reaction rate.

4. a)

$$\text{rate} = \frac{77.6\,\text{mL} - 40.9\,\text{mL}}{20.0\,\text{s}} = 1.84\,\text{mL/s}$$

↑ **1 mark** ↑ **1 mark**

   b) The rate of the reaction decreases because the concentration of HCl decreases as the reaction proceeds.

5.

$$\text{rate} = \frac{0.060\,\text{g H}_2}{60.0\,\text{s}} = \frac{0.060\,\text{g H}_2}{\text{min}}$$

← **1 mark**

$$\text{rate} = \frac{0.060\,\text{g H}_2}{\text{min}} \times \frac{1\,\text{mol H}_2}{2.0\,\text{g}}$$

$$= \frac{0.030\,\text{mol H}_2}{\text{min}}$$

← **1 mark**

$$\text{rate} = \frac{0.030\,\text{mol H}_2}{\text{min}} \times \frac{2\,\text{mol Al}}{3\,\text{mol H}_2}$$

$$= \frac{0.020\,\text{mol Al}}{\text{min}}$$

← **1 mark**

(Deduct $\frac{1}{2}$ **mark** for incorrect significant figures.)

6. Property: Mass ← ½ mark

Change and Explanation: Mass decreases because $CO_{2(g)}$ leaves the system. ← ½ mark

Property: pH ← ½ mark

Change and Explanation: pH increases because HCl is consumed. ← ½ mark

7. This rate of this reaction will increase if :
a) Increase surface area of Carbon b) Increase the concentration of Oxygen Gas, ie pressure
c) Increase the reaction temperature d) Introduce a catalyst

8. a) A reaction in which the reactants are in different phases.
b) Solid Mg reacting with hydrochloric acid.

9. A reaction in which all reactants are in the same phase. ← **1 mark**

e.g. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$ ← **1 mark**

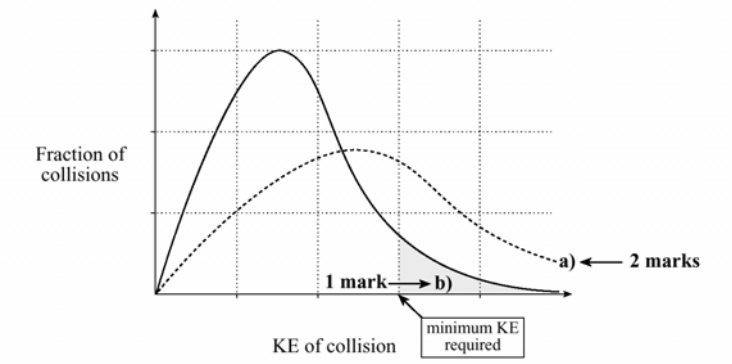
10.
- At a higher temperature there is a greater frequency of collisions. **1 mark**
- There is a higher percentage of collisions with sufficient energy. **1 mark**

11. Reason I: unfavourable collision geometry/orientation **1 mark**
Reason II: insufficient collision energy/low KE **1 mark**

12. a) ΔH = -394 kJ mol CO 2 ← **1 mark**
b) This reaction has a very high activation energy and therefore collisions will be unsuccessful.**1 mark**
c) The spark provides activation energy, therefore more effective collisions occur. ← **1 mark**
The large surface area provides for more collisions to occur. ← **1 mark**

13. A reaction does not occur if there is insufficient energy. **1 mark**
A reaction does not occur if there is incorrect geometry. **1 mark**

14.



15. short-lived or unstable or high PE **(1 mark)** chemical species **(1 mark)**

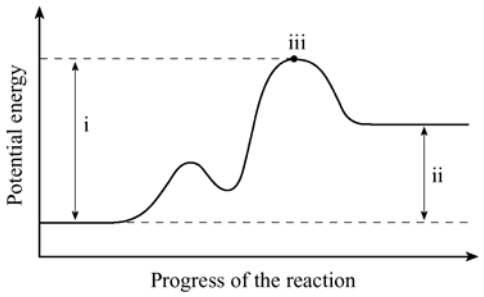
16. An *activated complex* is a short-lived, unstable, high energy chemical species that forms when reactant particles change to products.

17. *Activation energy* is the potential energy difference between the reactants and the activated complex. ← **2 marks**

18. If the activation energy is lower, then the rate of reaction is greater.

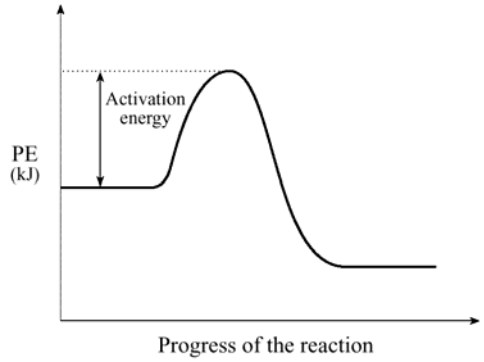
19. The platinum is acting as a catalyst, increasing the rate of this reaction by providing an alternate pathway that has a lower activation energy, therefore more particles undergo successful collisions.

20.



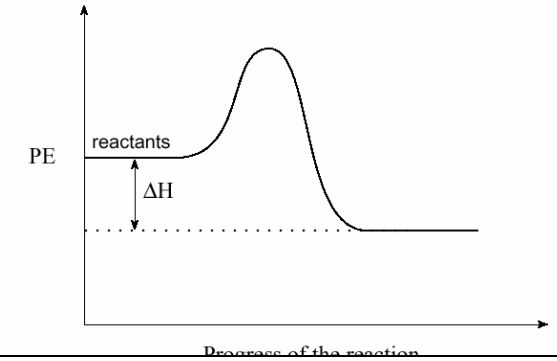
b) The reaction is endothermic in the forward direction.

21. a)



b) The minimum amount of potential energy required to produce an activated complex. **1 mark**

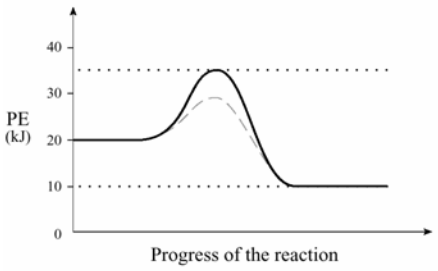
22.



1 mark for general shape
1 mark for ΔH

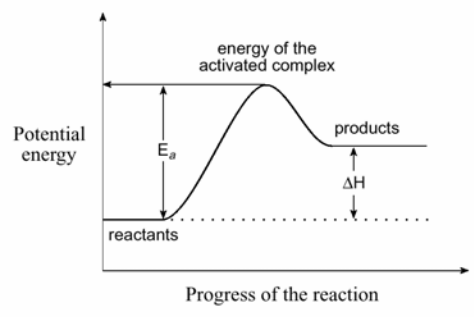
23. a) 15 kJ b) –10 kJ. c) 25 kJ.

d)



← 1 mark for diagram

24.



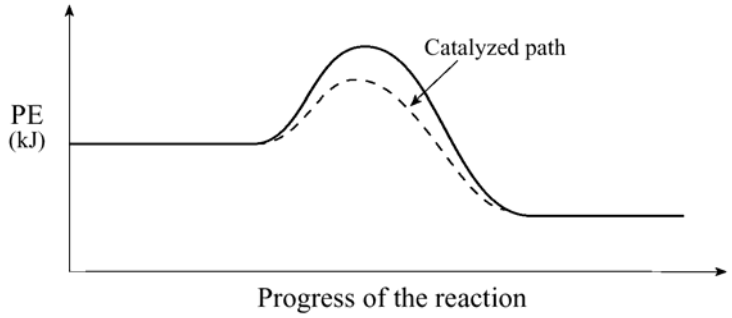
← **3 marks**

25. $2NH_3 + 92\ kJ \rightarrow N_2 + 3H_2$

26. • catalyst: offers second reaction path of lower activation energy
• increase in temperature: increases fraction of particles with sufficient energy to react
• increase in surface area: increases probability of collisions
• increase in concentration of oxygen: increases probability of collisions
(1mark for one of the above factors and **1mark** for appropriate explanation.)

27. This is a 5 particle collision and is unlikely to occur in one step.

28. $2H_2O_{2(\ell)} \rightarrow 2H_2O_{(\ell)} + O_{2(g)}$



a) The catalyzed graph has a lower activation energy.
b) The ΔH for catalyzed and uncatalyzed reactions are the same.

29. $Cl + CHCl_3 \rightarrow HCl + CCl_3$ ← **2 marks**

30. a) A 4 particle collision is unlikely.
bi)

$NO + N \rightarrow N_2O$ ← **2 marks**

ii)

N and N_2O ← **½ mark for each**

31. a)

$Sunlight + 2O_{3(g)} \rightarrow 3O_{2(g)}$

b) NO is the catalyst.
c) NO_2 or O are reaction intermediates
d) To supply activation energy.

32. a)

A reaction intermediate is NO_3 ← **1 mark**

b)

$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ ← **1 mark**

33. a)

$2ClO_2 + F_2 \rightarrow 2FClO_2$

b) F

34. a)

$NO + CO + O_2 \rightarrow NO_2 + CO_2$ ← **2 marks**

b) H and HOO **1 mark**
c) OH **1 mark**

35.

$HBr + HOOBr \rightarrow 2HOBr$ ← **2 marks**

36. a)

$2NO + 2H_2 \rightarrow N_2 + 2H_2O$ ← **1 mark**

b)

N_2O_2 and N_2O ← $\frac{1}{2}$ **mark for each**

37. a) $Cl_2 \rightarrow Cl + Cl$ **(2marks)**
b) Cl and H **(1mark)**