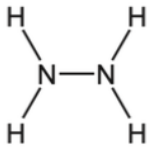
Energetics, rate and equilibrium

1. The compound hydrazine is used as a rocket fuel. It has the structural formula shown.



One of the reactions of hydrazine is shown. This reaction is exothermic.

$$N_2H_4 \rightarrow N_2 + 2H_2$$

The bond energies are shown in the table.

	bond energy in kJ / mol
H–H	+436
N–H	+390
N–N	+160
N≡N	+945

What is the energy change for this reaction?

A –339 kJ / mol **B** –97 kJ / mol **C** +97 kJ / mol **D** +339 kJ / mol

2. Which statement describes an exothermic reaction?

A The energy absorbed for bond breaking is greater than the energy released by bond formation.

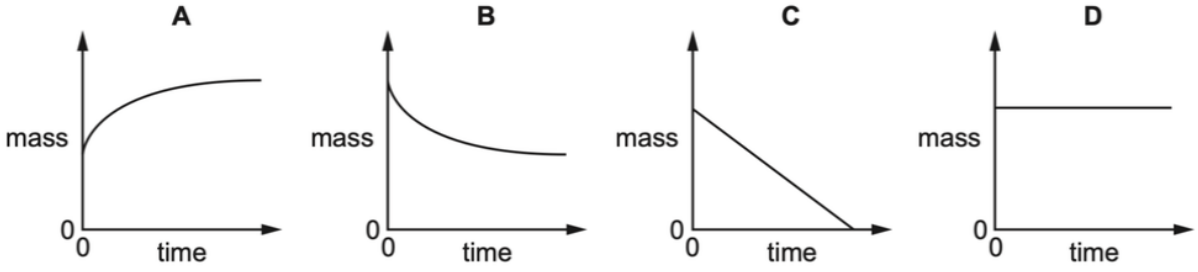
B The energy absorbed for bond breaking is less than the energy released by bond formation.

C The energy released by bond breaking is greater than the energy absorbed for bond formation.

D The energy released by bond breaking is less than the energy absorbed for bond formation.

3. The mass of a beaker and its contents is plotted against time.

Which graph represents what happens when sodium carbonate reacts with an excess of dilute hydrochloric acid in an open beaker?



4. Ethanoic acid reacts slowly with calcium carbonate.

Which statements explain why an increase in temperature increases the rate of the reaction?

1 The activation energy of the reaction is decreased.

2 There is an increase in collision rate.

3 The particles have more energy.

4 There will be fewer successful collisions.

A 1 and 2 **B** 1 and 3 **C** 2 and 3 **D** 2 and 4

5. Methane reacts with steam to produce hydrogen and carbon monoxide.

The equation for the reaction is shown.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$$

The reaction is reversible. The forward reaction is endothermic.

Which changes in temperature and pressure increase the equilibrium yield of carbon monoxide?

	temperature	pressure
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

6. The equation for the combustion of methane is shown.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The energy change for the combustion of methane is –890 kJ / mol.

The bond energies are shown in the table.

bond	bond energy in kJ / mol
C–H	+410
O=O	+496
H–O	+460

What is the bond energy of the C=O bond?

A +49 kJ / mol **B** +841 kJ / mol **C** +1301 kJ / mol **D** +1335 kJ / mol

7. Four statements about the effect of increasing temperature on a reaction are shown.

1 The activation energy becomes lower.

2 The particles move faster.

3 There are more collisions between reacting particles.

4 There are more collisions which have energy greater than the activation energy.

Which statements are correct?

A 1, 2 and 3 **B** 1, 3 and 4 **C** 2, 3 and 4 **D** 2 and 3 only

8. The formation of sulfur trioxide from sulfur dioxide is a reversible reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The forward reaction is exothermic.

Which changes would increase the equilibrium yield of SO_3?

1 increasing the pressure

2 lowering the temperature

3 decreasing the concentration of oxygen

A 1, 2 and 3 **B** 1 and 2 only **C** 1 only **D** 2 and 3 only

9. Some bond energies are shown in the table.

bond	bond energy in kJ / mol
H–H	+436
O=O	+496
H–O	+460

Hydrogen reacts with oxygen. The reaction is exothermic.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

What is the energy change for the reaction?

A –3208 kJ / mol

B –908 kJ / mol

C –472 kJ / mol

D –448 kJ / mol

10. Which statement about the effect of concentration and temperature on the rate of a reaction is **not** correct?

A If the concentration of a reactant is increased, the rate of reaction increases because more particles have sufficient energy to react.

B If the concentration of a reactant is increased, the rate of reaction increases because there are more collisions between particles per second.

C If the temperature is increased, the rate of reaction increases because there are more collisions between particles per second.

D If the temperature is increased, the rate of reaction increases because more particles have sufficient energy to react.

11. The following reaction has reached equilibrium in a closed system.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The forward reaction is exothermic.

Which row shows the effect of increasing the pressure on the equilibrium mixture?

	reaction rate	amount of SO_2	amount of SO_3
A	increases	decreases	increases
B	increases	increases	decreases
C	unchanged	decreases	increases
D	unchanged	increases	decreases

12. Which statements about exothermic and endothermic reactions are correct?

1 During an exothermic reaction, heat is given out.

2 The temperature of an endothermic reaction goes up because heat is taken in.

3 Burning methane in the air is an exothermic reaction.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

13. Chlorine reacts with ethane to produce chloroethane and hydrogen chloride.

The reaction is exothermic.

The bond energies are shown in the table.

bond	bond energy in kJ / mol
C–C*l*	+340
C–C	+350
C–H	+410
C*l*–C*l*	+240
H–C*l*	+430

What is the energy change for the reaction?

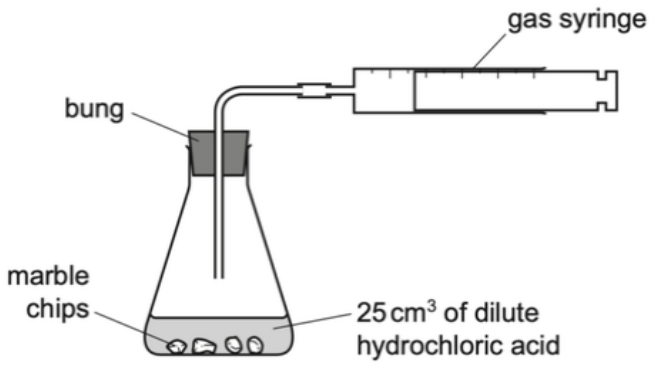
A –1420 kJ / mol

B –120 kJ / mol

C +120 kJ / mol

D +1420 kJ / mol

14. A student was investigating the reaction between marble chips and dilute hydrochloric acid.



Which changes slow down the rate of reaction?

	temperature of acid	concentration of acid	surface area of marble chips
A	decrease	decrease	decrease
B	decrease	decrease	increase
C	increase	decrease	decrease
D	increase	increase	increase

15. Nitrogen, hydrogen and ammonia gases are placed inside a container. The container is then sealed. After some time, an equilibrium forms.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which statement describes the equilibrium in this container?

A The amount of ammonia remains constant from the moment the container is sealed.

B The amounts of ammonia, nitrogen and hydrogen in the container are always equal.

C The rate of formation of ammonia is equal to the rate of decomposition of ammonia.

D The rate of formation of ammonia is faster than the rate of decomposition of ammonia.

16. The equation for the reaction between hydrogen and chlorine is shown.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

The reaction is exothermic.

The bond energies are shown in the table.

bond	bond energy in kJ / mol
Cl–Cl	+240
H–Cl	+430
H–H	+436

What is the energy change for the reaction?

A –1536 kJ / mol

B –184 kJ / mol

C +184 kJ / mol

D +246 kJ / mol

17. A gas is produced when calcium carbonate is heated.

Which type of change is this?

A chemical

B exothermic

C physical

D separation

18. The reaction used to manufacture ammonia from nitrogen and hydrogen is reversible.

An equilibrium can be established between ammonia, nitrogen and hydrogen.

Which statement describes the equilibrium?

A Both the forward reaction and the backward reaction have the same rate.

B The rate of the backward reaction is greater than the rate of the forward reaction.

C The rate of the forward reaction is greater than the rate of the backward reaction.

D The forward and backward reactions have both stopped.

19. Which statements about exothermic and endothermic reactions are correct?

1 During an exothermic reaction, heat is given out.

2 The temperature of an endothermic reaction goes up because heat is taken in.

3 Burning methane in the air is an exothermic reaction.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

20. Hydrogen and chlorine react to form hydrogen chloride.

The reaction is exothermic.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

The overall energy change for this reaction is –184 kJ / mol.

The table gives some of the bond energies involved.

bond	bond energy in kJ / mol
H–Cl	+430
H–H	+436

What is the energy of the Cl–Cl bond?

A –240 kJ / mol

B –190 kJ / mol

C +190 kJ / mol

D +240 kJ / mol

21. Hydrogen is produced when methane reacts with steam.

The equation for the reaction is shown.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

The forward reaction is endothermic.

Which conditions produce the highest yield of hydrogen?

	pressure	temperature
A	high	high
B	high	low
C	low	high
D	low	low

22. Ammonia is made by reacting nitrogen with hydrogen in the presence of an iron catalyst.

The reaction is exothermic.

The equation for the reaction is shown.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

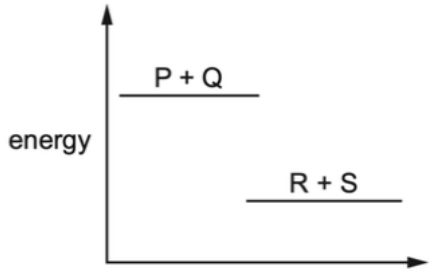
The bond energies are shown in the table.

bond	bond energy in kJ / mol
H–H	436
N–H	390
N≡N	945

What is the energy given out during this reaction?

A –4593 kJ / mol **B** –1083 kJ / mol **C** –959 kJ / mol **D** –87 kJ / mol

23. The energy level diagram for the reaction between P and Q to form R and S is shown.



Which row describes the energy changes involved and the type of reaction?

	energy changes involved	type of reaction
A	more energy is given out when the bonds in the products are formed than is needed to break the bonds in the reactants	endothermic
B	more energy is given out when the bonds in the products are formed than is needed to break the bonds in the reactants	exothermic
C	more energy is needed to break the bonds in the reactants than is given out when the bonds in the products are formed	endothermic
D	more energy is needed to break the bonds in the reactants than is given out when the bonds in the products are formed	exothermic

24. Copper(II) carbonate reacts with dilute sulfuric acid.

$$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$$

The rate of the reaction can be changed by varying the conditions.

Which changes always increase the rate of this chemical reaction?

1 increasing the concentration of sulfuric acid

2 increasing the size of the pieces of copper(II) carbonate

3 increasing the temperature

4 increasing the volume of sulfuric acid

A 1, 3 and 4 **B** 1 and 3 only **C** 2 and 3 **D** 3 and 4 only

25. The equation for the reversible reaction between hydrogen and iodine to form hydrogen iodide is shown.

The colours of the reactants and products are shown.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

colourless purple colourless

The forward reaction is exothermic.

Which statement is correct?

A An increase in pressure has no effect on the equilibrium position.

B The purple colour fades when the reaction mixture is heated.

C When equilibrium is reached, both forward and reverse reactions stop.

D When more hydrogen gas is added, the purple colour increases.

26. Which row describes an endothermic reaction?

	energy needed to break bonds / kJ	energy released by forming bonds / kJ	temperature
A	400	200	decreases
B	400	800	decreases
C	600	200	increases
D	600	800	increases

27. A reversible reaction is shown.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58\,kJ/mol$$

Which statement about an equilibrium mixture of NO_2 and N_2O_4 is correct?

A If the pressure is decreased the amount of N_2O_4 increases.

B If the temperature is increased the amount of N_2O_4 increases.

C The rates of formation and decomposition of N_2O_4 are not the same.

D The decomposition of N_2O_4 is an endothermic reaction.

28. Which statement about catalysts in chemical reactions is **not** correct?

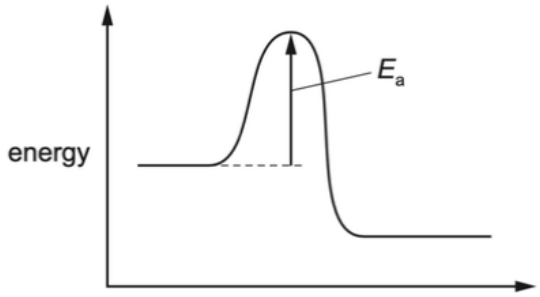
A Catalysts are not used up in the reaction.

B Catalysts increase the energy of the reacting particles.

C Catalysts increase the rate of the reaction.

D Catalysts lower the activation energy.

29. The diagram shows an energy level diagram for a reaction.



The diagram shows that the reaction is .....1..... .

Increasing the temperature increases the rate of reaction. A reason for this is that the .....2..... .

Which words correctly complete gaps 1 and 2?

	1	2
A	endothermic	activation energy decreases
B	endothermic	collision rate increases
C	exothermic	activation energy decreases
D	exothermic	collision rate increases

30. Hydrogen burns exothermically in oxygen.

The equation for the reaction is:

$$2H_2 + O_2 \rightarrow 2H_2O$$

The table shows the bond energies involved.

bond	bond energy in kJ / mol
H–H	436
O=O	498
O–H	464

What is the energy given out during the reaction?

A –3226 kJ / mol

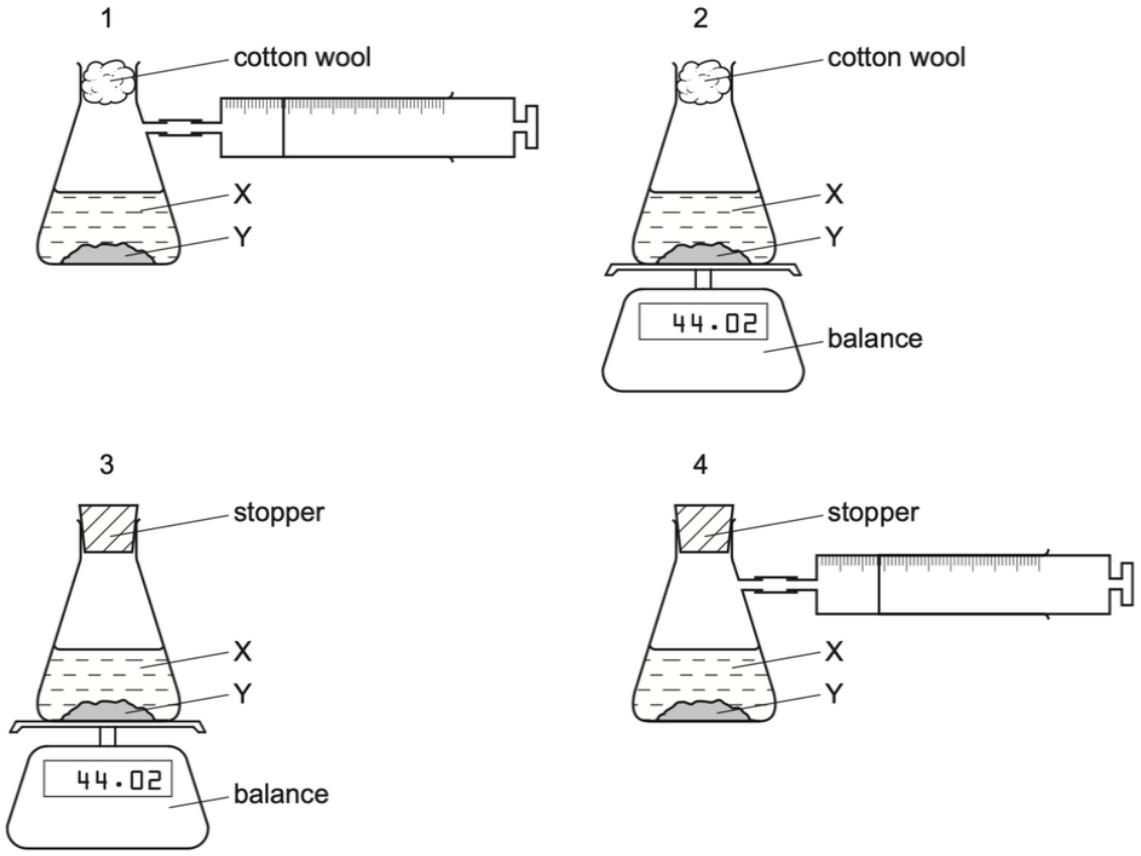
B –884 kJ / mol

C –486 kJ / mol

D –442 kJ / mol

31. A liquid X reacts with solid Y to form a gas.

Which two diagrams show suitable methods for investigating the rate (speed) of the reaction?



A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

32. Which statements explain why increasing temperature increases the rate of a chemical reaction?

1 Heat makes the molecules move faster and collide more often.

2 Heat makes the molecules collide with more energy so they are more likely to react.

3 Increasing temperature lowers the activation energy for the reaction.

A 1 and 2 **B** 1 and 3 **C** 1 only **D** 2 only

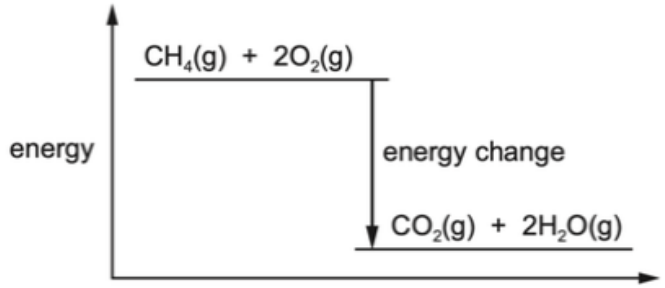
33. Steam reacts with carbon in an endothermic reaction.

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$$

Which conditions of temperature and pressure would give the largest yield of hydrogen?

	temperature	pressure
A	high	high
B	high	low
C	low	high
D	low	low

34. The energy level diagram for the combustion of methane is shown.



Which row gives the equation and energy change for this reaction?

	equation	energy change in kJ/mol
A	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	+891
B	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	–891
C	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	+891
D	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	–891

35. Which row describes how the energy of collision between particles changes when concentration and temperature are increased?

	concentration	temperature
A	increases	increases
B	increases	no change
C	no change	increases
D	no change	no change

36. Methanol is made by reacting carbon monoxide with hydrogen.

The reaction is exothermic and is a chemical equilibrium.

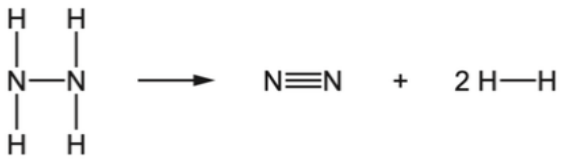
The equation for the reaction is shown.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Which changes in temperature and pressure increase the yield of methanol?

	temperature	pressure
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

37. Hydrazine, N_2H_4, decomposes as shown.



The energy change for this reaction is –95 kJ / mol.

The table shows some bond energies involved.

bond	bond energy in kJ / mol
N≡N	945
N–H	391
H–H	436

What is the bond energy of the N–N bond?

A 158 kJ / mol **B** 315 kJ / mol **C** 348 kJ / mol **D** 895 kJ / mol

38. Which row explains why increasing temperature increases the rate of reaction?

	particles collide more often	particles collide with more energy
A	✓	✓
B	✓	✗
C	✗	✓
D	✗	✗

39. Methanol is manufactured by reacting carbon monoxide and hydrogen together in the presence of an aluminium oxide catalyst.

The equation for the reaction is shown.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The reaction is a reversible reaction.

The forward reaction is exothermic.

Which change in conditions increases the yield of methanol?

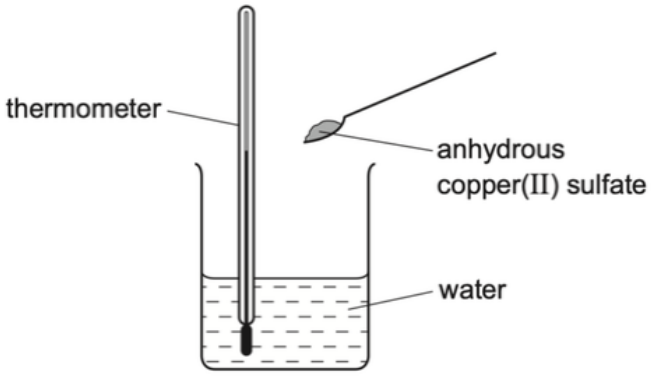
A decreasing the concentration of the carbon monoxide

B increasing the pressure

C increasing the rate of the reaction

D increasing the temperature

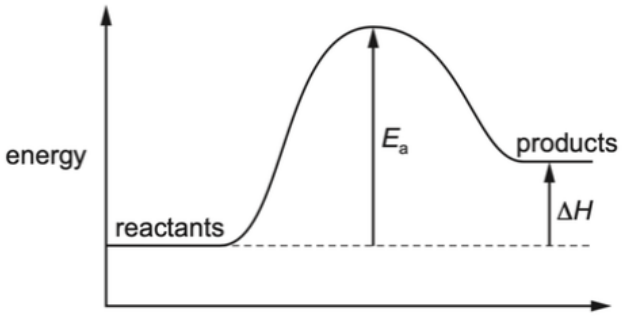
40. When anhydrous copper(II) sulfate is added to water a solution is formed and heat is given out.



Which row shows the temperature change and the type of reaction taking place?

	temperature change	type of reaction
A	decrease	endothermic
B	decrease	exothermic
C	increase	endothermic
D	increase	exothermic

41. The energy level diagram for a reaction is shown.



Which statement is **not** correct for this energy level diagram?

A It could be the energy level diagram for the reaction when petrol is burnt.

B Less energy is released in bond forming than is needed for bond breaking.

C The activation energy, E_a, has a positive value.

D The energy change, ΔH, for the reaction is positive.

42. Which statement explains why coal dust forms an explosive mixture with air?

A Coal dust catalyses the explosion.

B Coal dust has a large surface area.

C Crushing coal increases the concentration of the coal.

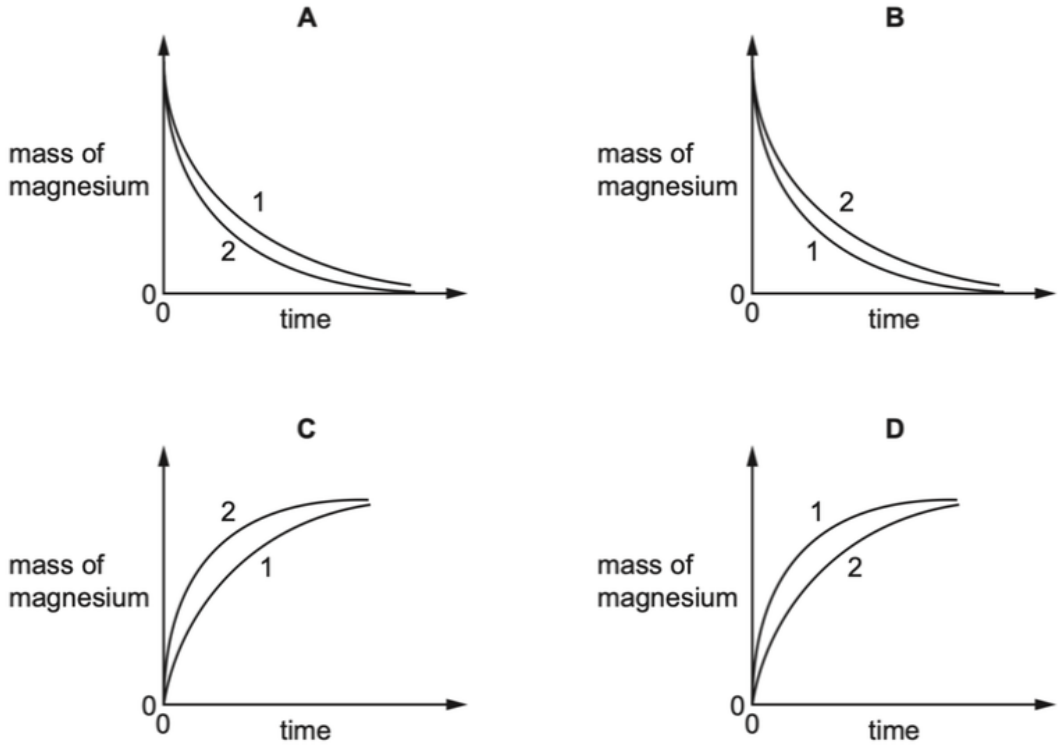
D Crushing coal increases the temperature of the coal.

43. The rate of reaction between magnesium and excess dilute hydrochloric acid was followed by measuring the mass of magnesium present at regular time intervals.

Two experiments were performed.

Both experiments used 0.1 g of magnesium ribbon. The acid in experiment 1 was less concentrated than in experiment 2.

Which graph shows the results of the experiments?



44. Which statement explains why coal dust forms an explosive mixture with air?

A Coal dust catalyses the explosion.

B Coal dust has a large surface area.

C Crushing coal increases the concentration of the coal.

D Crushing coal increases the temperature of the coal.

45. The following reversible reaction takes place in a closed vessel at constant temperature.

$$P(g) + Q(g) + R(g) \rightleftharpoons S(g) + T(g)$$

When the system has reached equilibrium, more T is added.

After the addition of T, which substances increase in concentration?

A P, Q, R and S

B P and Q only

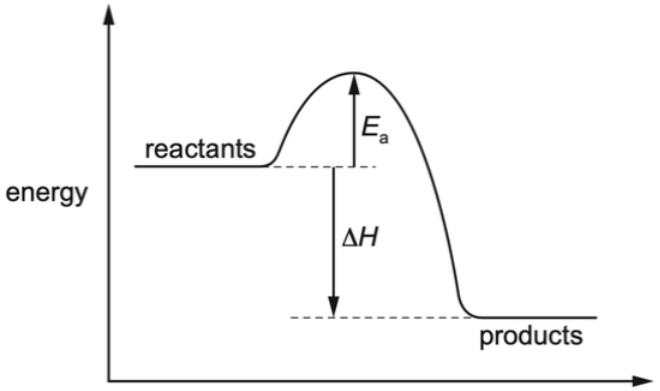
C P, Q and R only

D S only

46. Which experiment is the most exothermic?

	initial temperature / °C	final temperature / °C
A	20	5
B	20	32
C	25	12
D	25	34

47. The energy level diagram for a reaction is shown.



Which row is correct?

	sign of ΔH	overall energy change	sign of E_a
A	–	exothermic	–
B	+	endothermic	+
C	+	endothermic	–
D	–	exothermic	+

48. In an experiment nitric acid is added to excess marble chips and the volume of carbon dioxide formed is measured.

The experiment is repeated using smaller marble chips. All other conditions remain the same.

Which statement about the second experiment is correct?

A The collisions are more frequent and higher energy.

B The collisions are more frequent and the same energy.

C The collisions are the same frequency and the same energy.

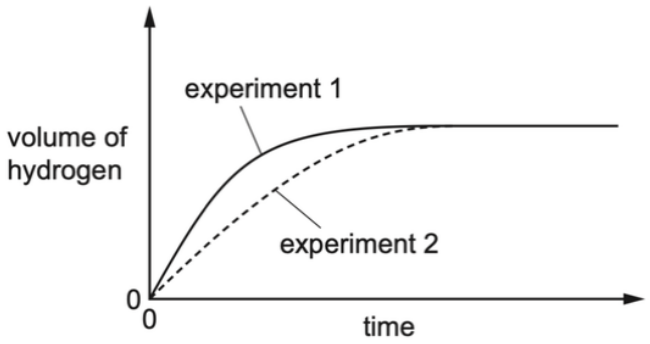
D The collisions are the same frequency and higher energy.

49. Zinc granules are reacted with excess dilute hydrochloric acid.

The volume of hydrogen given off is measured at different times.

The results are shown on the graph, labelled experiment 1.

The results for a second experiment are also shown on the graph, labelled experiment 2.



Which change to the conditions was made in experiment 2?

A The concentration of the hydrochloric acid was decreased.

B The size of the zinc granules was decreased.

C The surface area of the zinc granules was increased.

D The temperature was increased.

50. At 400 °C the reaction between hydrogen and iodine reaches an equilibrium. The reaction is exothermic.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -13\,kJ/mol$$

Which change in conditions would increase the percentage of hydrogen iodide in the equilibrium mixture?

A a decrease in pressure

B a decrease in temperature

C an increase in pressure

D an increase in temperature

51. 10 g of ammonium nitrate are added to water at 25 °C and the mixture stirred. The ammonium nitrate dissolves and, after one minute, the temperature of the solution is 10 °C.

Which word describes this change?

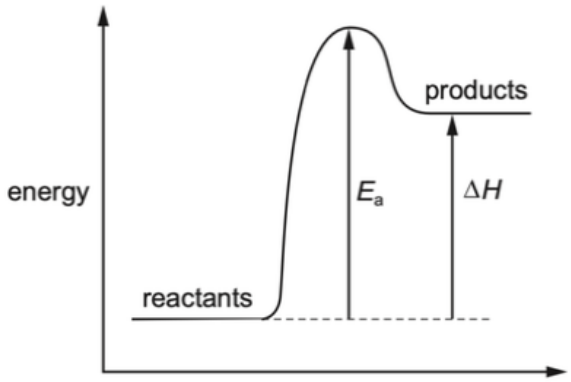
A endothermic

B exothermic

C neutralisation

D reduction

52. The energy level diagram for a reaction is shown.



Which row is correct?

	sign of ΔH	overall energy change	sign of E_a
A	–	exothermic	–
B	+	endothermic	+
C	+	endothermic	–
D	+	exothermic	+

53. Which change in conditions increases the energy of the particles in a reaction?

A addition of a catalyst

B increase in concentration

C increase in surface area

D increase in temperature

54. Chlorine can be manufactured by the following reaction. The reaction is exothermic.

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

Which change increases the yield of chlorine at equilibrium?

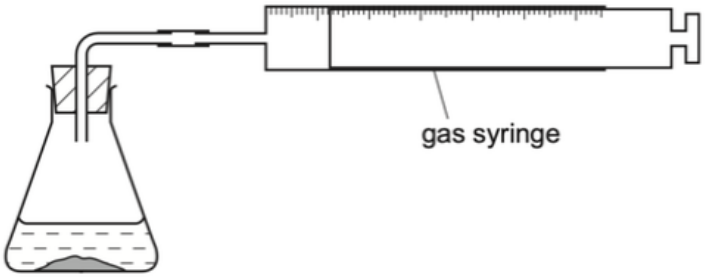
A adding more $HCl(g)$

B adding more $H_2O(g)$

C decreasing the pressure

D increasing the temperature

55. An experiment X is carried out between a solid and a solution using the apparatus shown.

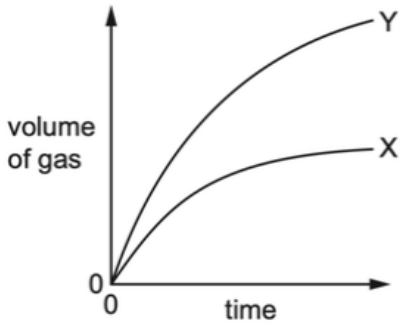


The volume of gas given off is measured at different times and the results plotted on a graph.

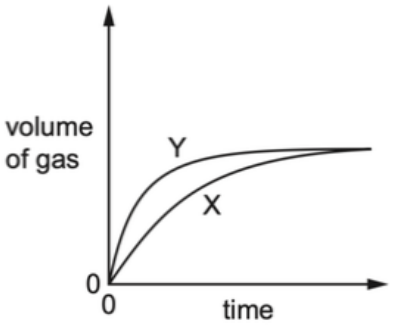
In a second experiment Y, the surface area of the solid is increased but all other factors remain the same.

Which graph shows the results of experiments X and Y?

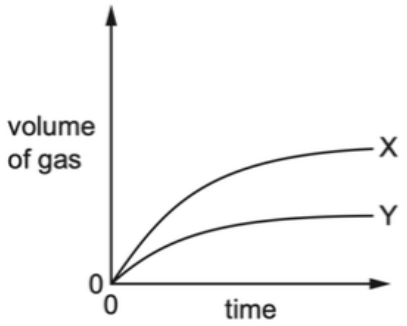
A



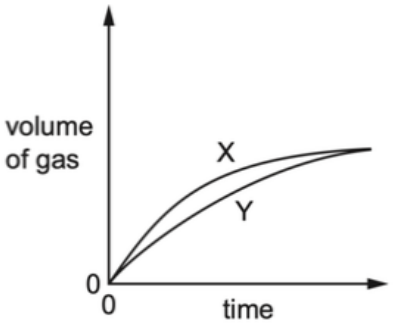
B



C



D



56. Nitryl chloride, NO_2Cl, reacts with nitric oxide, NO. The forward reaction is exothermic.

$$NO_2Cl(g) + NO(g) \rightleftharpoons NO_2(g) + NOCl(g)$$

The reaction can reach equilibrium.

(a) What is meant by the term *equilibrium* for a reversible reaction?

.....

.....

..... [2]

(b) Explain why increasing the temperature increases the rate of reaction.

.....

.....

..... [3]

(c) State and explain the effect, if any, of increasing the temperature on the position of equilibrium.

.....

.....

..... [2]

(d) State and explain the effect, if any, of decreasing the pressure on the position of equilibrium.

.....

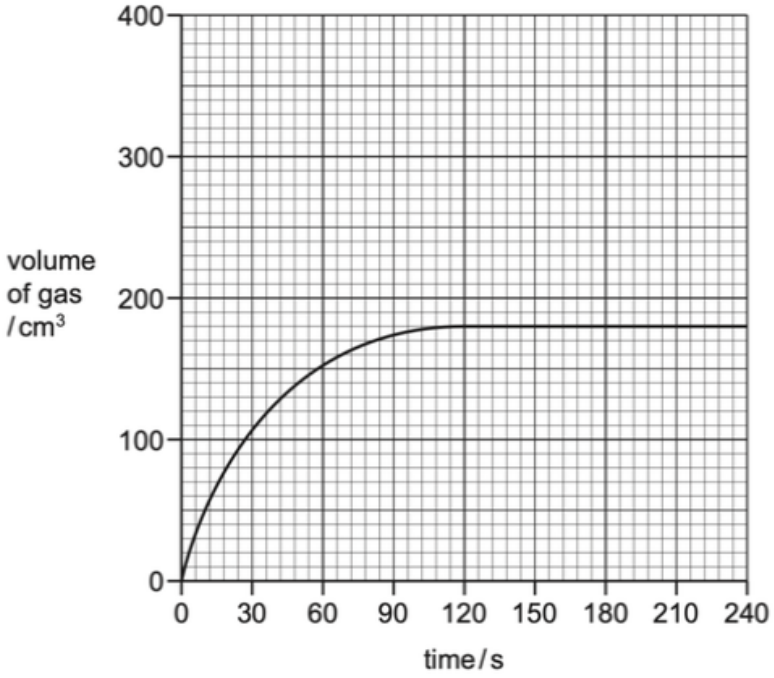
.....

..... [2]

57. When barium carbonate is added to dilute hydrochloric acid, carbon dioxide gas is formed.

A student carried out an experiment to measure the volume of gas formed as a reaction proceeds. The student added a small mass of powdered barium carbonate to an excess of 0.1 mol/dm^3 hydrochloric acid. A graph of the results was drawn.

The graph is shown.



(a) Name the **two** pieces of apparatus needed to take the measurements shown on the graph.

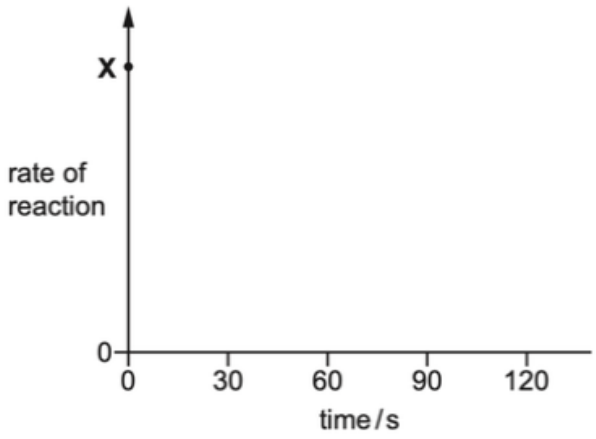
1 .....

2 .....

[1]

(b) On the axes below, sketch a graph to show how the rate of reaction changes as the reaction proceeds.

Assume the initial rate of reaction is represented by the point at **X**.



[2]

(c) The total volume of gas collected was 180 cm^3 at room temperature and pressure.

Calculate the mass, in grams, of barium carbonate used.

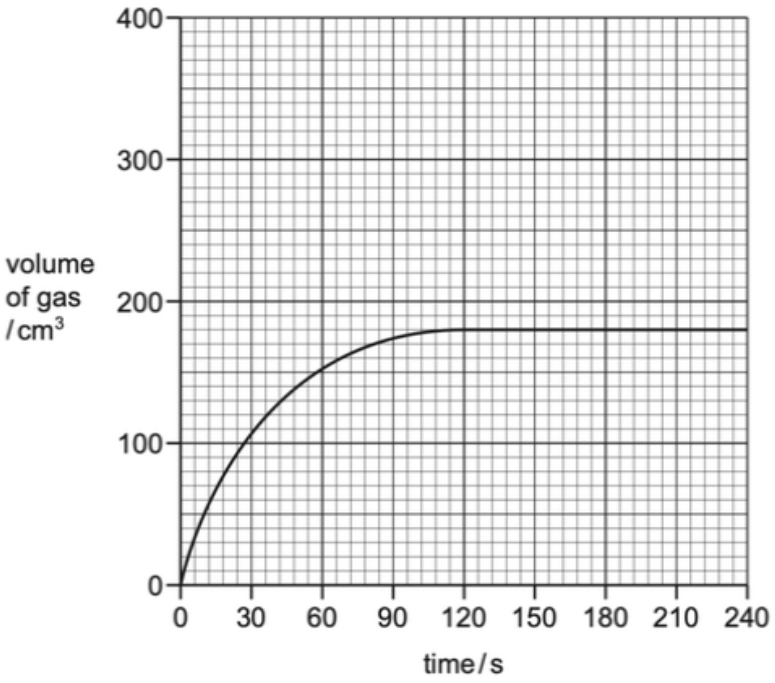
$$BaCO_3 + 2HCl \rightarrow BaCl_2 + H_2O + CO_2$$

mass of barium carbonate = ... g [3]

(d) The original graph has been drawn again.

On the grid, draw the graph expected if the same mass of barium carbonate is added as large lumps instead of as a powder. All other conditions are the same as in the original experiment.

Explain why your graph is different from the original graph.



.....

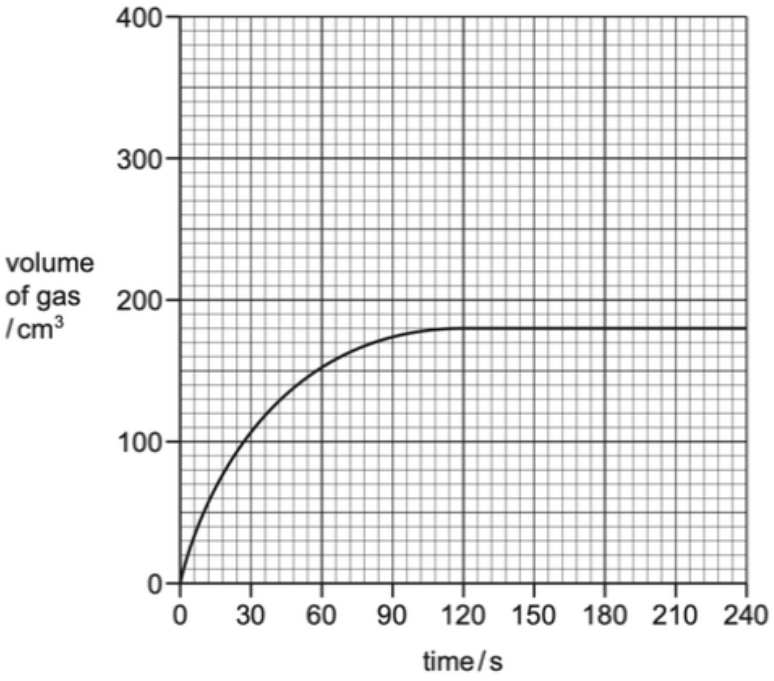
.....

..... [2]

(e) The original graph has been drawn again.

On the grid, draw the graph expected if the concentration of dilute hydrochloric acid is changed from 0.1 mol / dm^3 to 0.2 mol / dm^3. All other conditions are the same as in the original experiment.

Explain, in terms of particles, why your graph is different from the original graph.



.....

.....

.....

..... [4]

(f) The experiment is changed and the mass of powdered barium carbonate is doubled. All other conditions are the same as in the original experiment. The acid is still in excess.

Deduce the volume of gas formed at room temperature and pressure, in cm^3, in this experiment.

volume of gas = ... cm^3 [1]

58. This question is about nitrogen and some of its compounds.

(a) Nitrogen in the air can be converted into ammonia by the Haber process. The chemical equation for the reaction is shown.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

(i) State the temperature and pressure used in the Haber process.

temperature .....

pressure .....

[2]

(ii) Name the catalyst used in the Haber process.

..... [1]

(b) The ammonia produced in the Haber process can be oxidised to nitrogen(II) oxide at 900 °C. The reaction is exothermic.

(i) Balance the chemical equation for this reaction.

$$4NH_3 + ...O_2 \rightleftharpoons .....NO + ...H_2O$$

[2]

(ii) Suggest a reason, other than cost, why a temperature greater than 900 °C is **not** used.

..... [1]

(iii) Suggest a reason why a temperature less than 900 °C is **not** used.

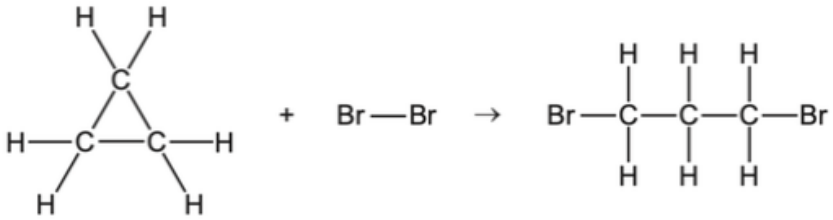
..... [1]

(c) Nitrogen(II) oxide can be reacted with oxygen and water to produce nitric acid as the only product.

Write a chemical equation for this reaction.

..... [2]

59. Cyclopropane is a colourless gas.
Cyclopropane reacts with bromine at room temperature. The chemical equation for the reaction is shown.



cyclopropane + bromine → dibromopropane

(a) (i) What is the empirical formula of cyclopropane?

..... [1]

(ii) What colour change, if any, would you see when cyclopropane is bubbled into aqueous bromine?

initial colour .....

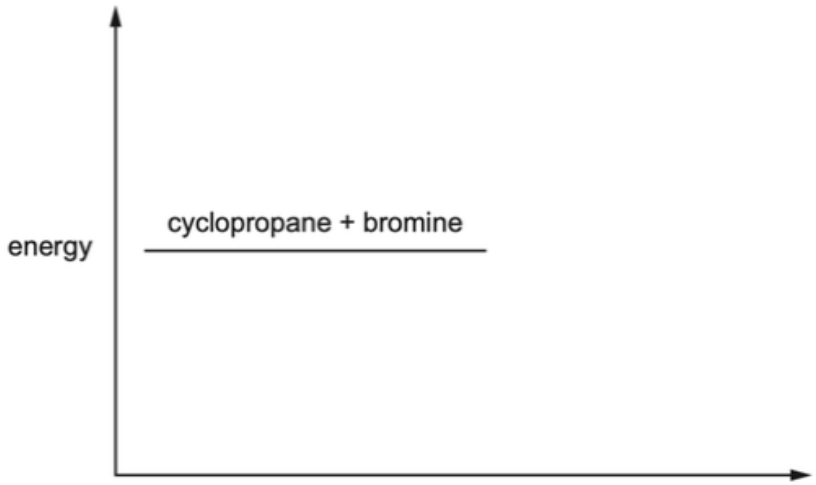
final colour .....

[2]

(b) The reaction of cyclopropane with bromine is exothermic.

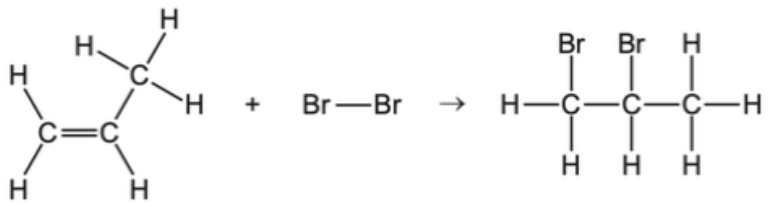
(i) Complete the energy level diagram for this reaction by

- adding the product of the reaction,
- labelling the energy change, ΔH.



[2]

(ii) Propene also reacts with bromine.



Use the bond energies in the table to calculate the energy change, ΔH, for the reaction.

	C–H	C–C	Br–Br	C–Br	C=C
bond energy in kJ/mol	412	348	193	285	611

energy change = ... kJ/mol [3]

(c) The boiling point of bromine is 59 °C and the boiling point of iodine is 184 °C.

Explain why iodine has a higher boiling point than bromine.

.....

.....

.....

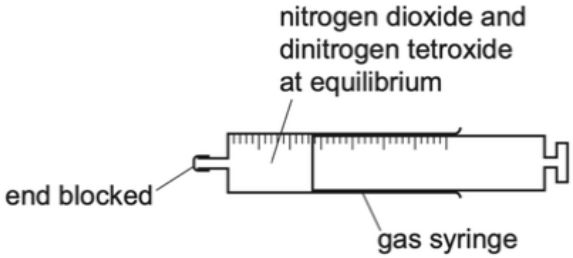
.....

..... [2]

60. Nitrogen dioxide, NO_2, exists in equilibrium with dinitrogen tetroxide, N_2O_4.
Nitrogen dioxide is brown and dinitrogen tetroxide is colourless.

$$\underset{\text{brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)}$$

(i) A sample of nitrogen dioxide and dinitrogen tetroxide at equilibrium was placed in a closed gas syringe.
The syringe plunger was pushed in. This increased the pressure in the gas syringe. The temperature was kept constant.



State how the colour of the gas in the syringe changed. Explain your answer in terms of the position of the equilibrium.

.....

.....

.....

..... [3]

(ii) A sealed tube containing nitrogen dioxide and dinitrogen tetroxide at equilibrium was cooled in an ice bath at constant pressure. The contents of the tube became paler.

Suggest an explanation for this observation in terms of the position of the equilibrium.

.....

.....

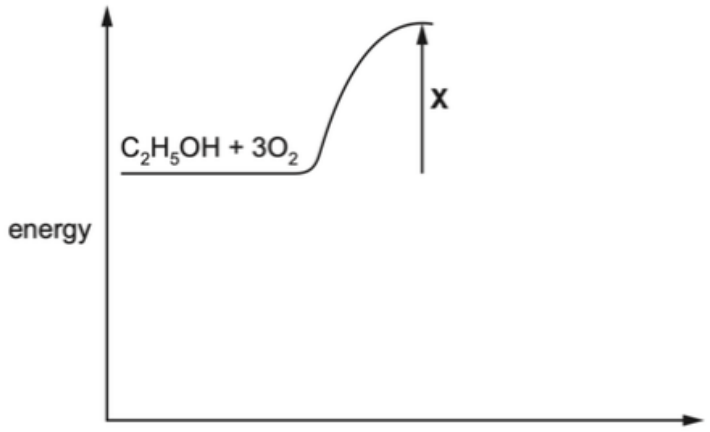
..... [2]

61. The chemical equation for the complete combustion of ethanol, C_2H_5OH, is shown.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

The energy released when one mole of ethanol undergoes complete combustion is 1280 kJ.

Part of the energy level diagram for this reaction is shown.



(a) Complete the energy level diagram to show
- the products of the reaction,
- the overall energy change of the reaction.

[3]

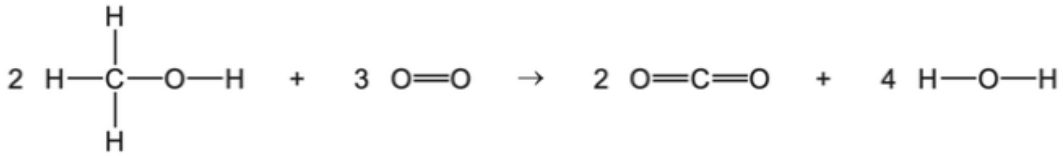
(b) What does **X** represent?

..... [1]

(c) The chemical equation for the complete combustion of methanol, CH_3OH, is shown.

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$$

The equation can be represented as shown.



Use the bond energies in the table to determine the energy change, ΔH, for the complete combustion of **one** mole of methanol.

bond	bond energy in kJ/mol
C–H	410
C–O	360
O–H	460
O=O	500
C=O	805

- energy needed to break bonds

..... kJ

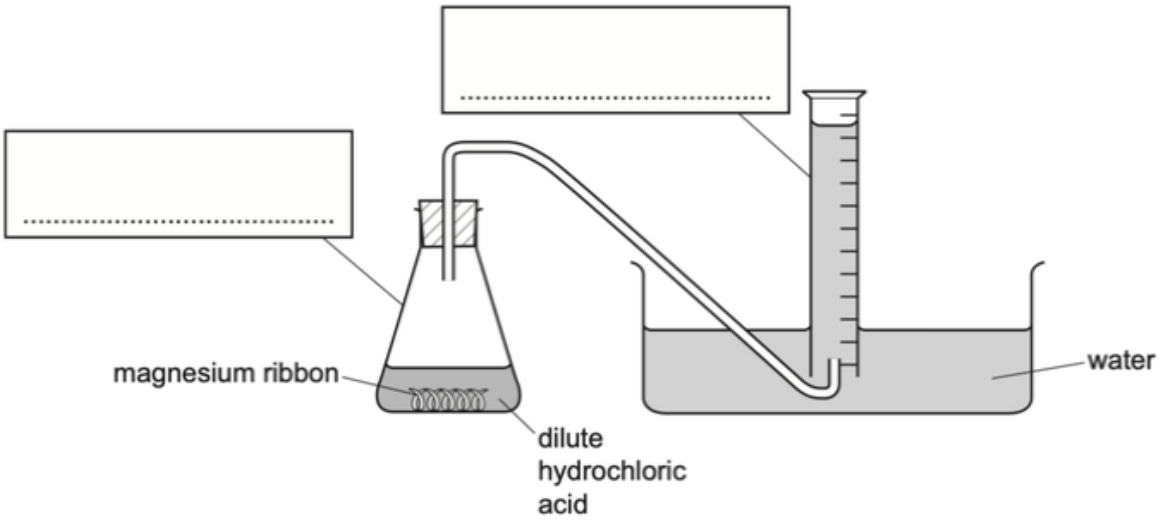
- energy released when bonds are formed

..... kJ

- energy change, ΔH, for the complete combustion of **one** mole of methanol

..... kJ/mol
[4]

62. A student investigated the rate of reaction between an excess of dilute hydrochloric acid and magnesium ribbon. The apparatus is shown.



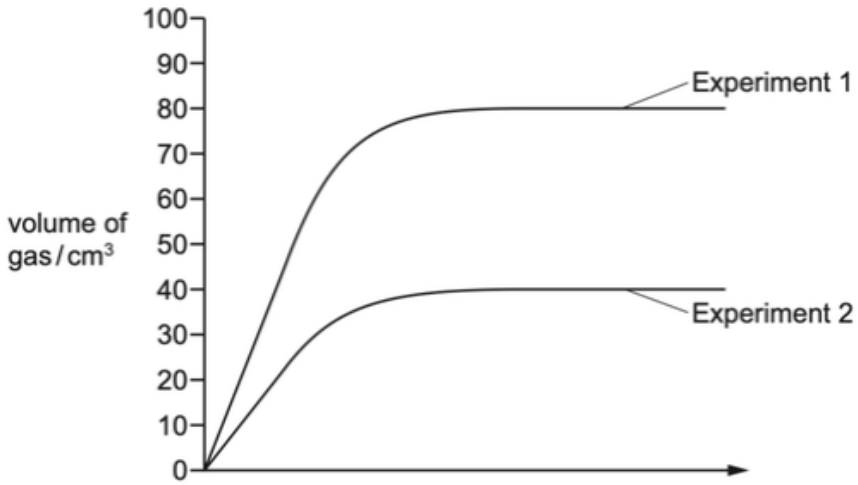
Two experiments were carried out. The temperature was the same in each case.

(a) Complete the boxes to identify the apparatus. [2]

(b) Give **one** observation expected during this reaction.

..... [1]

Graphs were drawn from the results for each experiment as shown.



(c) Label the *x*-axis of the graph. [2]

(d) (i) Give the volumes of gas at which the **two** graphs level out and compare these values.

.....

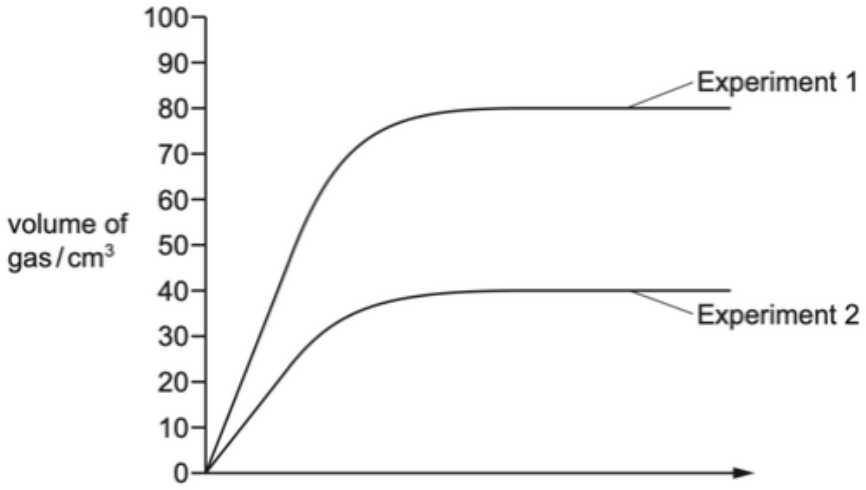
..... [2]

(ii) Suggest why the graphs level out at different volumes.

..... [1]

(iii) The graph has been drawn again.

Draw the curve expected if Experiment 1 were repeated using the same mass of magnesium powder instead of magnesium ribbon.



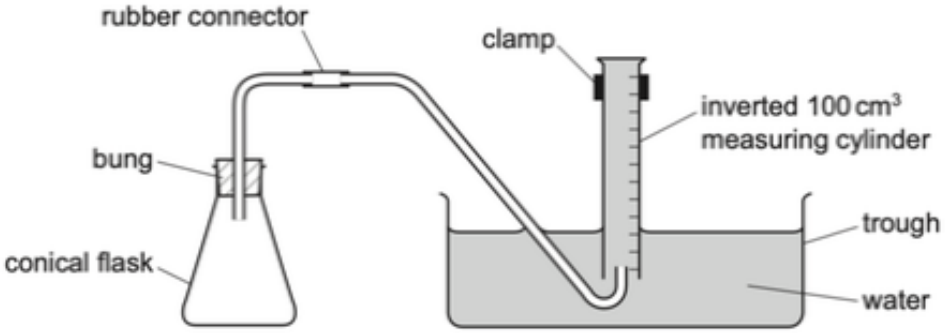
[2]

63. A student investigated the rate of reaction between magnesium ribbon and two different solutions of dilute sulfuric acid, solution **G** and solution **H**. The acid was in excess in both experiments.

Two experiments were carried out.

Experiment 1

- The apparatus was set up as shown in the diagram.

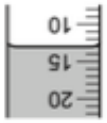
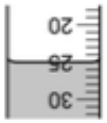
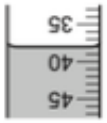
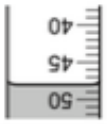
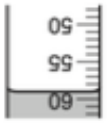
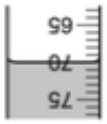
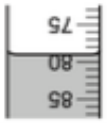
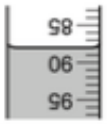
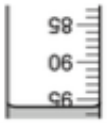


- Using a measuring cylinder, 50 cm^3 of solution **G** were poured into the conical flask. A piece of magnesium ribbon was added to the conical flask and the bung replaced.
- The timer was started immediately and the total volume of gas collected in the measuring cylinder was measured every 20 seconds for 180 seconds (3 minutes).

Experiment 2

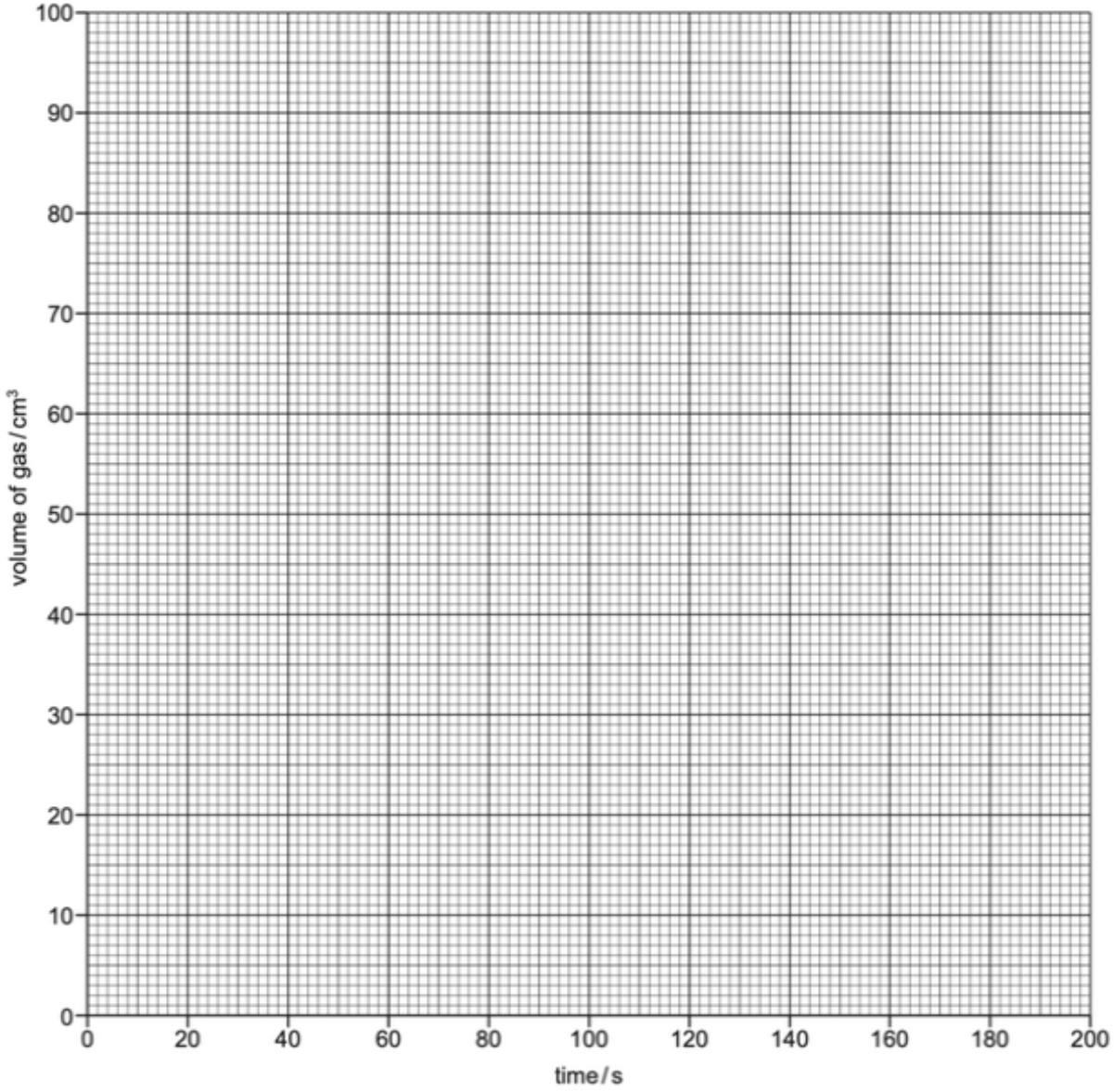
- Experiment 1 was repeated using 50 cm^3 of solution **H** instead of solution **G**.

(a) Use the measuring cylinder diagrams to record the volumes of gas collected in Experiment 1.

	Experiment 1		Experiment 2
time / s	measuring cylinder diagram	volume of gas / cm^3	volume of gas / cm^3
0			0
20			8
40			14
60			21
80			27
100			33
120			39
140			45
160			50
180			55

[3]

(b) Plot the results for Experiments 1 and 2 on the grid and draw **two** smooth line graphs. Clearly label your graphs.



[4]

(c) Which experiment had the faster rate of reaction? Suggest a reason why the rate was faster in this experiment.

.....

..... [2]

(d) The average rate of this reaction can be calculated using the equation shown.

$$\text{average rate} = \frac{\text{volume of gas / cm}^3}{\text{time taken / s}}$$

For Experiment 1, calculate the average rate of reaction for the first 30 seconds of the reaction. Include the units.

rate = ...

units = ...
[3]

(e) Why, eventually, will no more gas be produced?

..... [1]

(f) Suggest the effect on the rate of reaction of using the same mass of magnesium powder instead of magnesium ribbon. Explain your answer.

.....

.....

..... [2]

(g) Give **one** advantage and **one** disadvantage of using a measuring cylinder to measure the volumes of solution **G** and solution **H**.

advantage .....

disadvantage .....
[2]

(h) Suggest **one** improvement to these experiments.

.....

..... [1]

64. A student investigated what happened when two different solids, **S** and **T**, dissolved in water.

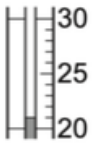
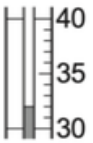
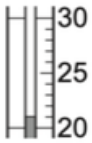
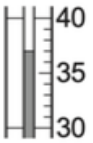
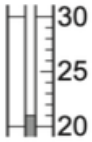
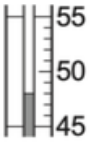
Two experiments were carried out.

Experiment 1

- Using a measuring cylinder, 30 cm^3 of distilled water were poured into a polystyrene cup. The initial temperature of the water was measured.
- 2.0 g of solid **S** were added to the polystyrene cup and the solution was stirred with a thermometer.
- The **maximum** temperature of the solution was measured.
- The solution was poured away and the polystyrene cup was rinsed out with distilled water.

- The procedure was repeated using 3.0 g of solid **S**.
- The procedure was repeated using 5.0 g of solid **S**.

(a) Use the thermometer diagrams to record the temperatures in the table.

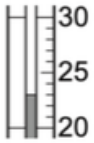
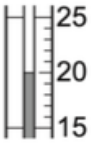
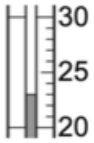
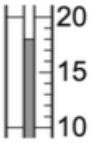
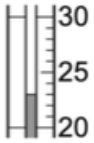
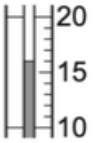
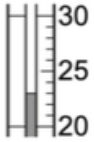
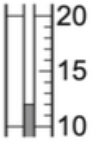
mass of solid **S** / g	thermometer diagram	initial temperature of the water / °C	thermometer diagram	maximum temperature of the solution / °C
2.0				
3.0				
5.0				

[2]

Experiment 2

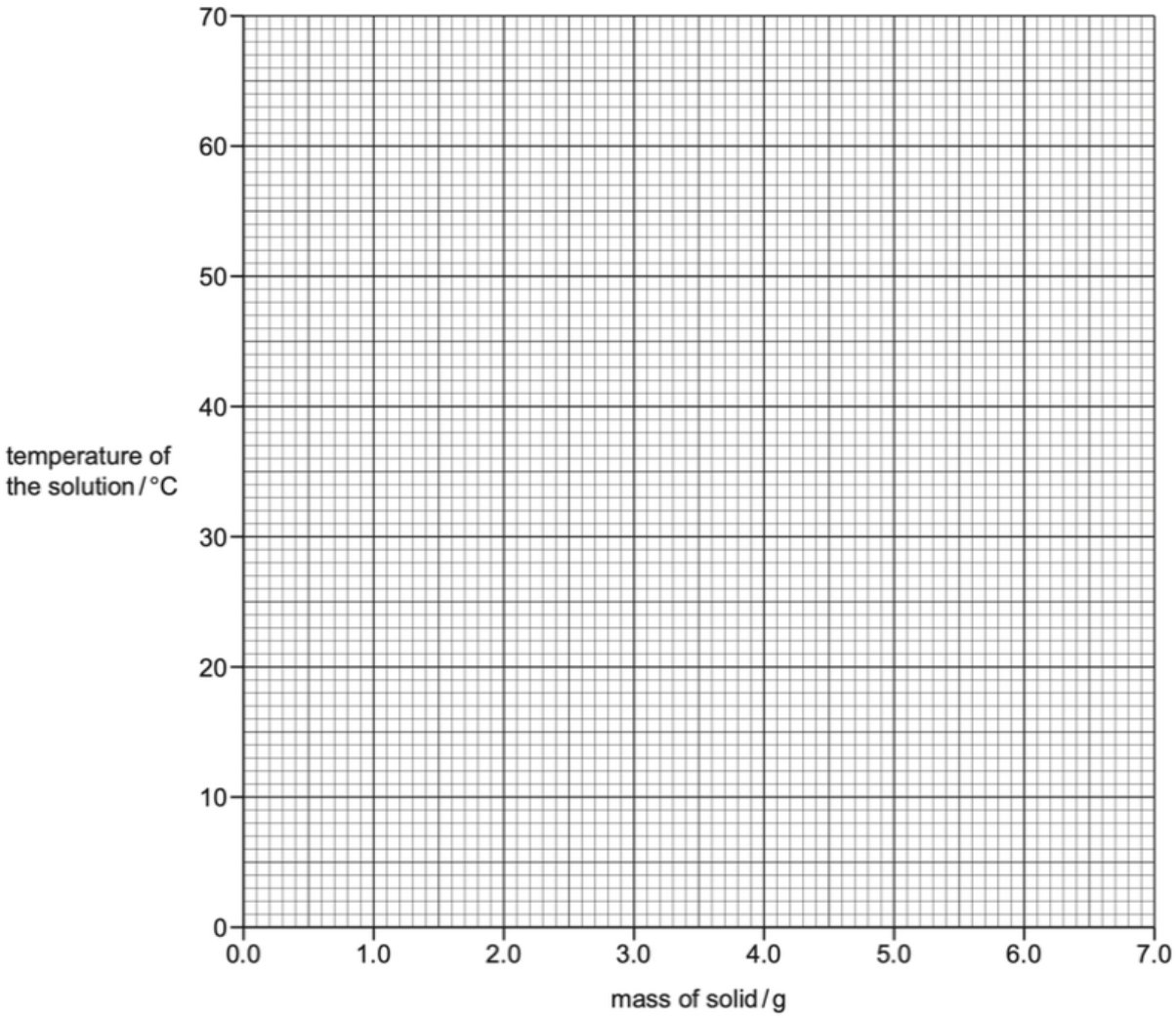
- Experiment 1 was repeated using 2.0 g, 3.0 g, 4.0 g and 6.0 g of solid **T**. The **minimum** temperature of the solution was measured in each case.

(b) Use the thermometer diagrams to record the temperatures in the table.

mass of solid **T** / g	thermometer diagram	initial temperature of the water / °C	thermometer diagram	minimum temperature of the solution / °C
2.0				
3.0				
4.0				
6.0				

[2]

(c) Plot the results of Experiment 1 (maximum temperature) and Experiment 2 (minimum temperature) on the grid. Draw **two** straight lines of best fit.
Clearly label your lines.



[4]

(d) (i) **From your graph**, deduce the maximum temperature of the solution if 6.0 g of solid **S** were added to 30 cm^3 of distilled water.

Show clearly **on the grid** how you worked out your answer.

..... °C [2]

(ii) **From your graph**, deduce the minimum temperature of the solution if 4.5 g of solid **T** were added to 30 cm^3 of distilled water.

Show clearly **on the grid** how you worked out your answer.

..... °C [2]

(e) Use the results to identify the type of energy change that occurs when solid **S** dissolves in water.

..... [1]

(f) Suggest **one** change you could make to the experiments to obtain more accurate results. Explain how this change would make the results more accurate.

change .....

explanation .....

.....

[2]

(g) Suggest how the reliability of the results could be checked.

..... [1]

(h) Explain how the temperatures measured would be different if Experiment 1 were repeated using 60 cm^3 of distilled water in each case.

.....

..... [2]