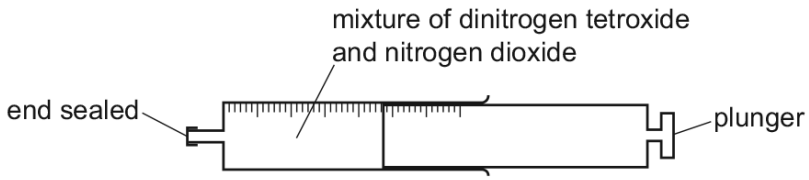
## 7.3 Reversible reactions

01. 0620_s21_qp_41 Q: 4

Dinitrogen tetroxide, $N_2O_4$, decomposes into nitrogen dioxide, $NO_2$. The reaction is reversible.

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

A gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide gases was sealed and heated. After reaching equilibrium the mixture was a pale brown colour.




**(a)** State what is meant by the term *equilibrium*.

.....

.....

..... [2]

**(b)** The plunger of the gas syringe is pushed in. The temperature does not change. The mixture initially turns darker brown. After a few seconds the mixture turns lighter brown because the equilibrium shifts to the left.

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

**(i)** Explain why the mixture initially turns darker brown.

..... [1]

**(ii)** Explain why the position of equilibrium shifts to the left.

..... [1]

**(c)** The forward reaction is endothermic.

**(i)** State what happens to the position of equilibrium when the temperature of the mixture is increased.

..... [1]

**(ii)** State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is increased.

rate of the forward reaction .....

rate of the backward reaction .....

[2]

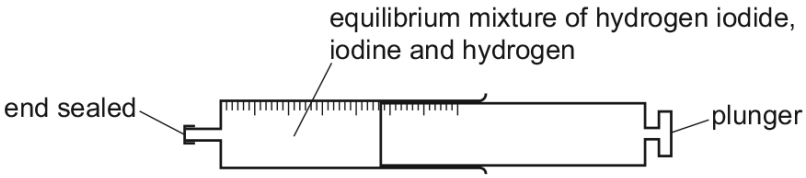
[Total: 7]

02. 0620_s21_qp_43 Q: 4

Hydrogen iodide, HI, decomposes into iodine and hydrogen. The reaction is reversible.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

A gas syringe containing a mixture of hydrogen iodide, iodine and hydrogen gases was sealed. After reaching equilibrium the mixture was a pale purple colour.




**(a)** State what is meant by the term *equilibrium*.

.....

.....

..... [2]

**(b)** The plunger of the gas syringe is pushed in. The position of equilibrium does not change. The colour of the gaseous mixture turns darker purple.

The temperature remains constant.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

**(i)** Explain why the position of equilibrium does **not** change.

..... [1]

**(ii)** Suggest why the colour of the gaseous mixture turns darker purple even though the position of equilibrium does not change.

..... [1]

**(c)** The forward reaction is endothermic.

**(i)** State what happens to the position of equilibrium when the temperature is decreased.

.....

..... [1]

**(ii)** State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is decreased.

rate of the forward reaction .....

rate of the backward reaction .....
[2]

[Total: 7]

---

03. 0620_w21_qp_42 Q: 4

Chlorine reacts with carbon monoxide to produce phosgene gas, $COCl_2(g)$. A catalyst is used.

$$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g)$$

The reaction is exothermic.

**(a)** Explain why the reaction is exothermic in terms of the energy changes of bond breaking and bond making.

.....

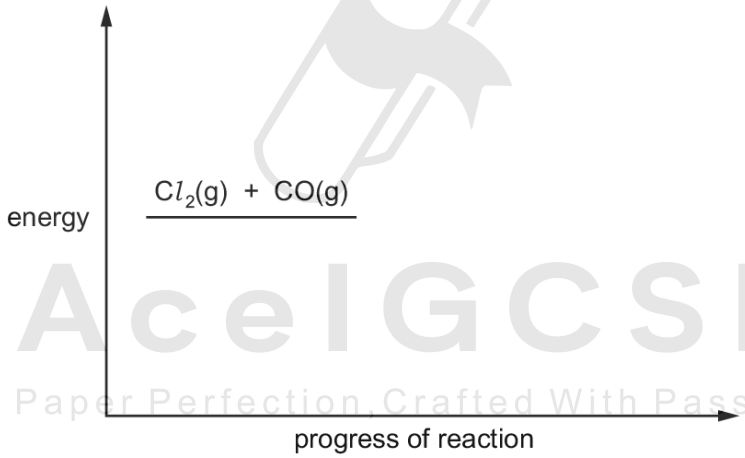
.....

..... [3]

**(b) (i)** Complete the energy level diagram for this reaction.

On your diagram show:

- the product of the reaction
- an arrow representing the energy change, labelled $\Delta H$
- an arrow representing the activation energy, labelled A.






[3]

**(ii)** State why a catalyst is used.

..... [1]

**(c)** Describe and explain the effect, if any, on the position of equilibrium when:

**(i)** the pressure is increased

.....

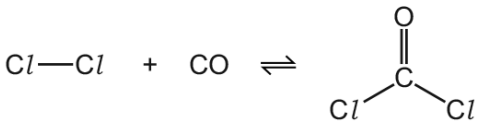
..... [2]

**(ii)** the temperature is increased.

.....

..... [2]

**(d)** The reaction between chlorine and carbon monoxide can be represented as shown.




When one mole of chlorine reacts with one mole of carbon monoxide, 230 kJ of energy is released.

Some bond energies are shown in the table.

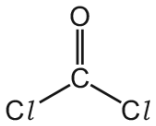
| bond | bond energy in kJ / mol |
|---|---|
| Cl–Cl | 240 |
| C=O | 745 |
| C–Cl | 400 |

Use the information to calculate the energy of the bond between the C and the O in carbon monoxide, CO.

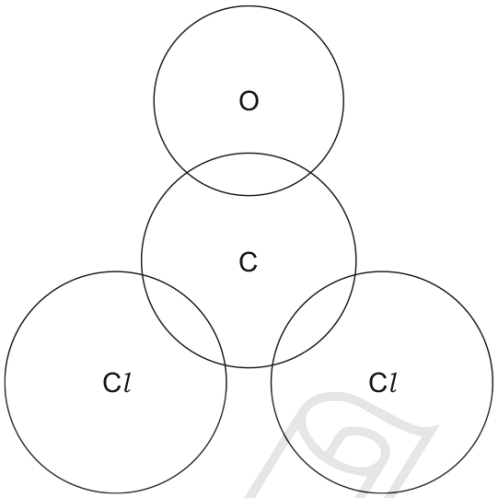


bond energy in carbon monoxide, CO = ..... kJ / mol [3]

**(e)** Complete the dot-and-cross diagram to show the electron arrangement in a molecule of $COCl_2$.




Show outer electrons only.




[3]

[Total: 17]

04. 0620_p20_qp_40 Q: 7

Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
An equilibrium forms between these iodine chlorides.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

**(a)** What do you understand by the term *equilibrium*?

.....

.....

..... [2]

**(b)** When the equilibrium mixture is heated, it becomes a darker brown colour.
Suggest if the reverse reaction is endothermic or exothermic. Give a reason for your choice.

.....

.....

..... [1]

**(c)** The pressure on the equilibrium mixture is decreased.

**(i)** How would this affect the position of equilibrium? Give a reason for your choice.

It would move to the .....

reason .....

..... [1]

**(ii)** Describe what you would observe.

.....

..... [1]

**(d)** Calculate the overall energy change for the reaction between iodine and chlorine using the bond energy values shown.

$$I_2 + Cl_2 \rightarrow 2ICl$$

| Bond | Energy / kJ per mol |
|---|---|
| I–I | 151 |
| Cl–Cl | 242 |
| I–Cl | 208 |

Show your working.

[3]

**(e)** Draw a labelled energy level diagram for the reaction between iodine and chlorine using the information in **(d)**.



[2]

[Total: 10]

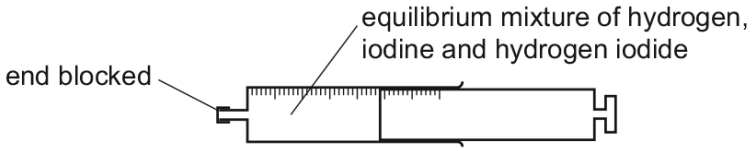
05. 0620_s18_qp_42 Q: 5

Hydrogen and iodine react together in a reversible reaction. Hydrogen iodide is formed.

$$\underset{\text{colourless gas}}{H_2(g)} + \underset{\text{purple gas}}{I_2(g)} \rightleftharpoons \underset{\text{colourless gas}}{2HI(g)}$$

The forward reaction is exothermic.

A gas syringe containing an equilibrium mixture of hydrogen, iodine and hydrogen iodide gases was sealed and heated to 250 °C. The equilibrium mixture was a pale purple colour.




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

.....

.....

..... [2]

**(b)** The plunger of the gas syringe was pressed in while the end of the gas syringe was blocked. This increased the pressure. The position of the equilibrium did **not** change. The colour of the gaseous mixture turned darker purple.

**(i)** Give a reason why the position of the equilibrium did **not** change.

..... [1]

**(ii)** Suggest why the gaseous mixture turned darker purple, even though the position of the equilibrium did **not** change.

..... [1]

**(c)** The temperature of the gas syringe was increased to 300 °C.

**(i)** What happened to the **position** of the equilibrium when the temperature of the gas syringe was increased from 250 °C to 300 °C?

..... [1]

**(ii)** What happened to the **rate** of the forward reaction and the **rate** of the backward reaction when the temperature of the gas syringe was increased from 250 °C to 300 °C?

rate of the forward reaction .....

rate of the backward reaction .....

[2]

[Total: 7]

06. 0620_w18_qp_41 Q: 5

Hydrogen gas reacts with iodine gas. The equation is shown.

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

The reaction is reversible and can reach equilibrium.

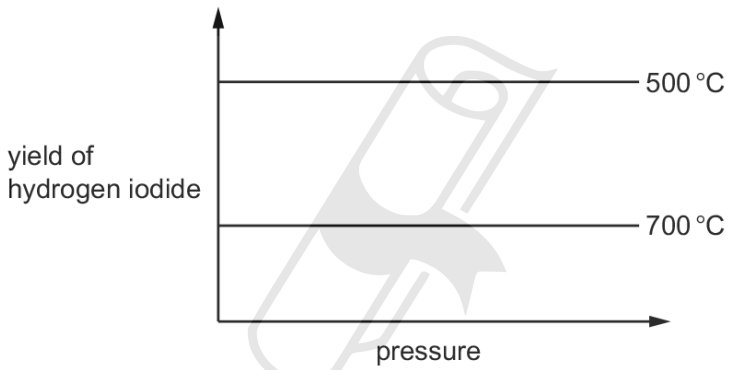
**(a)** What is meant by the term *equilibrium*?

.....

.....

..... [2]

**(b)** The graphs show how pressure affects the yield of hydrogen iodide, HI, at two different temperatures.




**(i)** Explain why the yield at 500 °C does **not** change as the pressure is increased.

.....

..... [1]



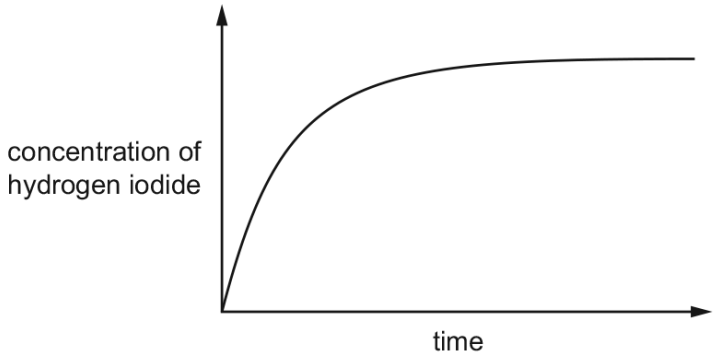
**(ii)** What can you conclude from the difference in the yield of hydrogen iodide at the **two** temperatures shown? Explain your answer.

.....

.....

..... [2]

**(c)** The graph shows how the concentration of hydrogen iodide, HI, changes after hydrogen gas and iodine gas are mixed together in a sealed container.




**(i)** When is the rate of reaction fastest?

..... [1]

**(ii)** The reaction was repeated at the same temperature and pressure but in the presence of a catalyst.

Draw a graph on the same axes to show how the concentration of hydrogen iodide changes with time in the presence of a catalyst. [2]

**(d)** A mixture of hydrogen gas and iodine gas is allowed to reach equilibrium.

**(i)** Increasing the pressure of a gas increases its concentration.

State and explain the effect of increasing the pressure on the **rate** of the forward reaction.

.....

.....

..... [2]



**(ii)** State and explain the effect of increasing the temperature on the **rate** of the reverse reaction.

.....

.....

.....

.....

..... [3]

[Total: 13]

07. 0620_m17_qp_42 Q: 3

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.

.....

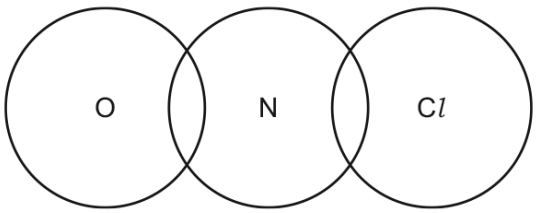
.....

..... [2]

**(e)** Nitrosyl chloride, NOC*l*, is a gas at room temperature. It has the structure shown.

$$O{=}N{-}Cl$$

**(i)** Complete the dot-and-cross diagram to show the arrangement of the outer shell electrons in nitrosyl chloride.




[2]

**(ii)** Nitrosyl chloride has a boiling point of –6 °C.

Explain why nitrosyl chloride has a low boiling point.

.....

.....

..... [2]

[Total: 13]

08. 0620_w17_qp_42 Q: 5

Some chemical reactions are reversible.

**(a)** Aqueous potassium chromate(VI), $K_2CrO_4$, is a yellow solution.

Aqueous potassium dichromate(VI), $K_2Cr_2O_7$, is an orange solution.

The two compounds interconvert when the pH of the solution changes.

$$\underset{\text{yellow}}{2K_2CrO_4} + H_2SO_4 \rightleftharpoons \underset{\text{orange}}{K_2Cr_2O_7} + K_2SO_4 + H_2O$$

Solution **Y** is a mixture of aqueous potassium chromate(VI) and aqueous potassium dichromate(VI) at equilibrium.

- Explain, in terms of the position of the equilibrium, what you would **see** if sulfuric acid were added to solution **Y**.

.....

.....

.....

- Explain, in terms of the position of the equilibrium, what you would **see** if sodium hydroxide were added to solution **Y**.

.....

.....

.....

..... [5]

**(b)** Hydrogen can be manufactured using a reversible reaction between methane and steam.

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

At 900 °C, in the presence of a nickel catalyst, the yield of hydrogen is 70%.

**(i)** What volume of hydrogen is produced from 100 $cm^3$ of methane under these conditions?

..... $cm^3$ [2]

Under different conditions, different yields of hydrogen are obtained.

**(ii)** If the pressure is increased, the yield of hydrogen becomes less than 70%.

Explain why, in terms of the position of the equilibrium.

.....

..... [1]

**(iii)** If the temperature is decreased, the yield of hydrogen decreases.

What does this information indicate about the reaction between methane and steam?

..... [1]

**(iv)** Why is a catalyst used in this reaction?

..... [1]

[Total: 10]

09. 0620_p16_qp_40 Q: 7

Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
An equilibrium forms between these iodine chlorides.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

**(a)** What do you understand by the term *equilibrium*?

.....

.....

..... [2]

**(b)** When the equilibrium mixture is heated, it becomes a darker brown colour.
Suggest if the reverse reaction is endothermic or exothermic. Give a reason for your choice.

.....

.....

..... [1]

**(c)** The pressure on the equilibrium mixture is decreased.

**(i)** How would this affect the position of equilibrium? Give a reason for your choice.

It would move to the .....

reason .....

..... [1]

**(ii)** Describe what you would observe.

.....

..... [1]

**(d)** Calculate the overall energy change for the reaction between iodine and chlorine using the bond energy values shown.

$$I_2 + Cl_2 \rightarrow 2ICl$$

| Bond | Energy / kJ per mol |
|---|---|
| I–I | 151 |
| Cl–Cl | 242 |
| I–Cl | 208 |

Show your working.

[3]

**(e)** Draw a labelled energy level diagram for the reaction between iodine and chlorine using the information in **(d)**.

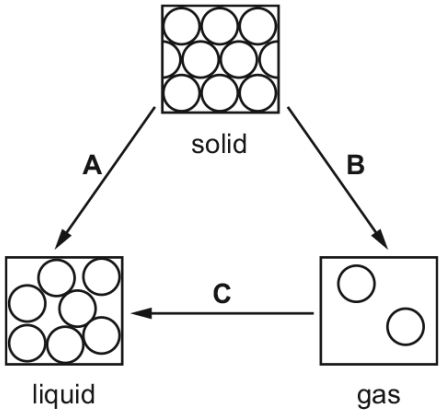


[2]

[Total: 10]

10. 0620_w16_qp_41 Q: 2

Matter can exist as solid, liquid or gas. The arrows show some changes of state.




**(a)** Name the changes of state represented on the diagram.

**(i)** **A** ..... [1]

**(ii)** **B** ..... [1]

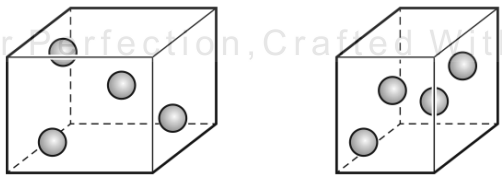
**(iii)** **C** ..... [1]

**(b)** Explain why energy has to be supplied to turn a liquid into a gas.

.....

..... [1]

**(c)** The diagrams represent the same number of particles of a gas in two containers, **D** and **E**, which have different volumes. The two containers are at the same temperature.




In which container will the pressure be higher? Explain your answer.

.....

.....

..... [1]

[Total: 5]

11. 0620_s14_qp_32 Q: 5

Carbonyl chloride is made from carbon monoxide and chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

**(a)** Two methods of preparing carbon monoxide are from methane and oxygen, and from methane and steam.

**(i)** The reaction between methane and oxygen can also form carbon dioxide. How can carbon monoxide be made instead of carbon dioxide?

..... [1]

**(ii)** The following reaction is used to make carbon monoxide and hydrogen.
The reaction is carried out at 1100 °C and normal pressure.

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

The reaction is reversible and comes to equilibrium. Suggest why a high temperature is used.

.....

.....

..... [2]

**(iii)** What is the disadvantage of using a high pressure for the reaction given in **(a)(ii)**?

.....

..... [2]

**(b)** Chlorine is made by the electrolysis of concentrated aqueous sodium chloride.
Describe this electrolysis. Write ionic equations for the reactions at the electrodes and name the sodium compound formed.

.....

.....

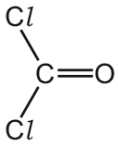
.....

.....

.....

..... [5]

**(c)** The structural formula of carbonyl chloride is given below.




Draw a diagram showing the arrangement of the valency electrons around the atoms in one molecule of this covalent compound.

Use o to represent an electron from an oxygen atom.
Use × to represent an electron from a chlorine atom.
Use ● to represent an electron from a carbon atom.

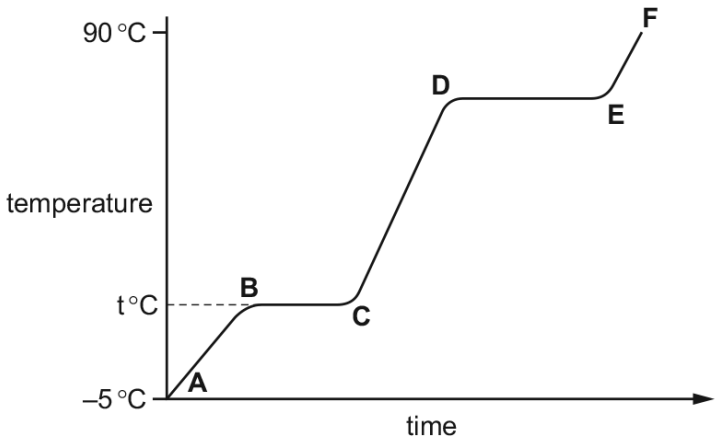
[3]

[Total: 13]

12. 0620_w14_qp_33 Q: 2

Compound X is a colourless liquid at room temperature.

**(a)** A sample of pure X was slowly heated from –5.0 °C, which is below its melting point, to 90 °C, which is above its boiling point. Its temperature is measured every minute and the results are represented on the graph.




**(i)** Complete the equation for the equilibrium present in the region **BC**.

X(s) ⇌ ..... [1]

**(ii)** What is the significance of temperature t °C?

..... [1]

**(iii)** What is the physical state of compound X in the region **EF**?

..... [1]

**(iv)** What would be the difference in the region **BC** if an impure sample of X had been used?

..... [1]



**(b)** Compound X is a hydrocarbon. It contains 85.7% of carbon. The mass of one mole of X is 84 g.

**(i)** What is the percentage of hydrogen in the compound ?

..... [1]

**(ii)** Calculate the empirical formula of X. Show your working.

empirical formula = ..... [3]

**(iii)** What is the molecular formula of compound X?

..... [1]

[Total: 9]

13. 0620_s13_qp_32 Q: 4

At present the most important method of manufacturing hydrogen is steam reforming of methane.

**(a)** In the first stage of the process, methane reacts with steam at 800 °C.

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

In the second stage of the process, carbon monoxide reacts with steam at 200 °C.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

**(i)** Explain why the position of equilibrium in the first reaction is affected by pressure but the position of equilibrium in the second reaction is not.

.....

.....

..... [2]

**(ii)** Suggest why a high temperature is needed in the first reaction to get a high yield of products but in the second reaction a high yield is obtained at a low temperature.

.....

..... [2]

**(b)** Two other ways of producing hydrogen are cracking and electrolysis.

**(i)** Hydrogen can be a product of the cracking of long chain alkanes.
Complete the equation for the cracking of $C_8H_{18}$.

$$C_8H_{18} \rightarrow 2..... + H_2$$ [1]

**(ii)** There are three products of the electrolysis of concentrated aqueous sodium chloride. Hydrogen is one of them.
Write an equation for the electrode reaction which forms hydrogen.

..... [2]

**(iii)** Name the other **two** products of the electrolysis of concentrated aqueous sodium chloride and give a use of each one.

product ..... use .....

product ..... use ..... [4]

[Total: 11]

14. 0620_w13_qp_31 Q: 3

Ammonia is manufactured by the Haber process.

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

The forward reaction is exothermic.

**(a)** Describe how the reactants are obtained.

**(i)** Nitrogen

.....

..... [2]

**(ii)** Hydrogen

.....

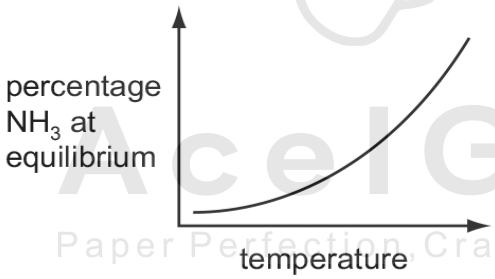
.....

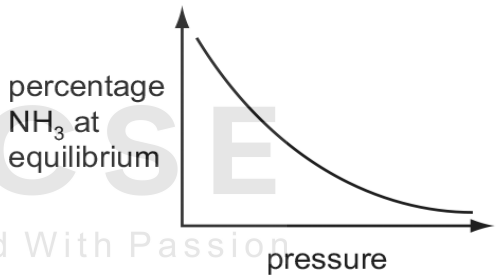
..... [3]

**(b)** The percentage of ammonia in the equilibrium mixture varies with temperature and pressure.

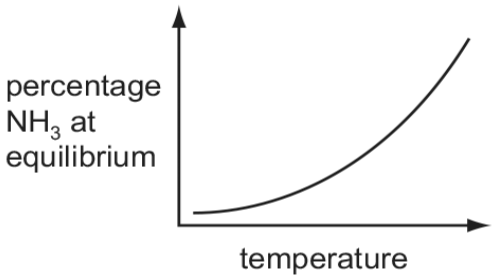
**(i)** Which pair of graphs, **A**, **B** or **C**, shows correctly how the percentage of ammonia at equilibrium varies with temperature and pressure?

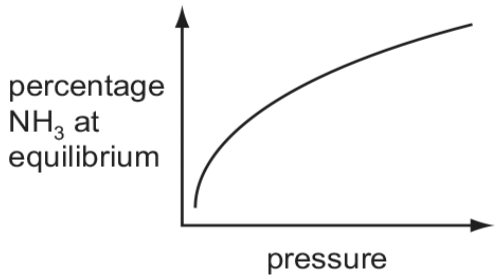
pair **A**



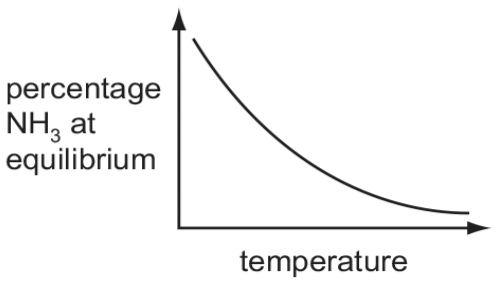



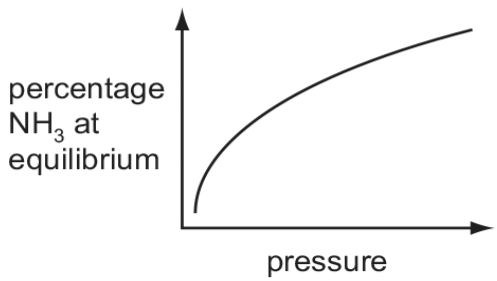

pair **B**




pair **C**




The pair with **both graphs correct** is ..... [1]

**(ii)** Give a full explanation of why the pair of graphs you have chosen in **(i)** is correct.

.....

.....

.....

.....

.....

.....

..... [6]

**(iii)** Catalysts do not alter the position of equilibrium. Explain why a catalyst is used in this process.

.....

.....

.....

..... [2]

[Total: 14]

01. 0620_s21_ms_41 Q: 4

| Question | Answer | Marks |
|---|---|---|
| (a) | the **rate** of forward reaction equals the rate of the reverse reaction (1)<br>**concentrations** of reactants and products are constant (1) | 2 |
| (b)(i) | (increased pressure) nitrogen dioxide **particles** or **molecules** (forced) close**r** together<br>**OR**<br>same number of nitrogen dioxide **particles** or **molecules** in a smalle**r** volume | 1 |

| Question | Answer | Marks |
|---|---|---|
| (b)(ii) | fewe**r** number of gas moles or molecules on left hand side or reactant side (of the equation) **ORA** | 1 |
| (c)(i) | shifts to the right | 1 |
| (c)(ii) | increase / faster (1)<br>increase / faster (1) | 2 |

02. 0620_s21_ms_43 Q: 4

| Question | Answer | Marks |
|---|---|---|
| (a) | the **rate** of forward reaction equals (the rate of the) reverse reaction (1)<br>concentrations of reactants and products are constant (1) | 2 |
| (b)(i) | same number of gas moles on both sides of the equilibrium / same number of gas molecules on both sides of the equilibrium | 1 |
| (b)(ii) | iodine **particles** or **molecules** (forced) closer together / same number of iodine **particles** or **molecules** in a smaller volume | 1 |
| (c)(i) | shifted to the left | 1 |
| (c)(ii) | decrease / slower (1)<br>decrease / slower (1) | 2 |

03. 0620_w21_ms_42 Q: 4

| Question | Answer | Marks |
|---|---|---|
| (a) | M1 E of making bonds > breaking bonds<br><br>M2 bond making releases energy<br><br>M3 bond breaking requires energy | 3 |
| (b)(i) | M1 exothermic mark<br>horizontal line below energy level to R.H.S. of reactants line<br>and<br>labelled $COCl_2(g)$ (1)<br><br>M2 activation E mark<br>activation energy 'hump' with upward arrow labelled A / activation energy (1)<br><br>M3 energy change mark<br>one downward arrow labelled $\Delta H$<br>and<br>energy change starting from E level of reactants and finishing at E level of products (1) | 3 |
| (b)(ii) | increases rate of reaction | 1 |
| (c)(i) | equilibrium shifts to right hand side (1)<br>fewer moles (of gas) on right hand side (1) | 2 |
| (c)(ii) | equilibrium shifts to left hand side (1)<br>(forward) reaction is exothermic (1) | 2 |

| Question | Answer | Marks |
|---|---|---|
| (d) | M1 bond energy in making bonds<br>= [(2 × 400) + 745] = 1545 (kJ mol–1)<br><br>M2 use of total E change<br>–230 = [240 + E(C≡O)] – 1545<br>OR<br>[240 + E(C≡O)] = –230 + 1545 = (+1315)<br><br>M3 E(C≡O)<br>= [–230 + 1545] – 240 = 1075 (kJ mol–1) | 3 |
| (e) | M1 all single bonding dot and cross pairs correct<br>M2 double C=O bond dot and cross pairs are correct<br>M3 complete diagram is correct | 3 |

04. 0620_p20_ms_40 Q: 7

**(a)** rates equal; [1]
concentrations do not change / macroscopic properties remain constant; [1]

**(b)** endothermic **and** because this direction is favoured by high temperatures; [1]
note: reason is required

**(c)** **(i)** move to left hand side / reactants favoured **and** because bigger volume / more moles on left hand side [1]
note: reason is required

**(ii)** less (yellow) solid / more (dark brown) liquid / green gas visible / turns darker brown / smell chlorine [1]
allow: ecf from **(c)(i)**

**(d)** (bond breaking =) 151 + 242 = 393; [1]
(bond making =) 208 □ 2 = –416; not: 416 [1]
(overall =) 393 – 416 = –23; allow: ecf [1]
note: sign must be given

**(e)** Any two from:
diagram shows exothermic reaction;
activation energy shown;
reactants and products labelled / both axes labelled;
note: labelling is one mark only
allow: ecf from **(d)** [2]

05. 0620_s18_ms_42 Q: 5

| | | |
|---|---|---|
| (a) | the rate of forward reaction equals (the rate of the) reverse reaction | 1 |
| | concentrations of reactants and products are constant | 1 |
| (b)(i) | same number of gas moles on both sides of the equilibrium / same number of gas molecules on both sides of the equilibrium | 1 |
| (b)(ii) | (increased pressure) particles or molecules (forced) closer together / same number of particles or molecules in a smaller volume | 1 |
| (c)(i) | to left / towards reactants / in reverse direction | 1 |
| (c)(ii) | increase / faster | 1 |
| | increase / faster | 1 |

06. 0620_w18_ms_41 Q: 5

| | | |
|---|---|---|
| (a) | **M1** forward and back reactions occur at equal rates | 1 |
| | **M2** concentration (of substances) remains constant | 1 |
| (b)(i) | equal / same number of moles on each side<br>**or**<br>amount / molecules (of gas) on each side is the same | 1 |
| (b)(ii) | **M1** (forward) reaction exothermic **or** reverse reaction endothermic<br>**M2** yield lower at higher temperature **or** (position of) equilibrium moves left at higher temperature ORA | 2 |
| (c)(i) | at the start / beginning | 1 |
| (c)(ii) | **M1** new line is steeper than printed line and starts at origin | 1 |
| | **M2** new line reaches same final volume as printed line | 1 |
| (d)(i) | **M1** Faster<br>**and**<br>More particles per unit volume / $dm^3$ / $cm^3$<br>**M2** More collisions per second / unit time or greater collision rate | 2 |
| (d)(ii) | Reaction faster **and** (particles) have more energy **or** (particles) move faster | 1 |
| | more collisions per second **or** greater collision rate | 1 |
| | more (of the) particles / collisions have energy greater than the activation energy **or** more particles / collisions have sufficient energy to react **or** a greater percentage / proportion / fraction of collisions are successful | 1 |

07. 0620_m17_ms_42 Q: 3

| | | |
|---|---|---|
| (a) | any 2 from:<br>□ forward and backward reactions occur at equal rates<br>□ amounts / moles / concentrations (of substances) remain constant<br>□ closed system | 2 |
| (b) | **M1** (particles) have more energy **OR** (particles) move faster | 1 |
| | **M2** more collisions per second **OR** greater collision rate | 1 |
| | **M3** more (of the) particles / collisions have energy greater than the activation energy **OR** more particles / collisions have sufficient energy to react **OR** a greater percentage / proportion / fraction of collisions are successful | 1 |
| (c) | **M1** equilibrium moves left / yield decreases | 1 |
| | **M2** because the forward reaction is exothermic **OR** because the reverse reaction is endothermic | 1 |
| (d) | **M1** no change | 1 |
| | **M2** numbers of moles of gas on each side is the same | 1 |
| (e)(i) | **M1** all bonding pairs correct (two pair of electrons shared between O and N **AND** one pair of electrons shared between N and C*l*) | 1 |
| | **M2** four non-bonding electrons on O **AND** two non-bonding electrons on N **AND** six non-bonding electrons on C*l* to give a fully correct diagram | 1 |
| (e)(ii) | **M1** weak forces (of attraction) | 1 |
| | **M2** between molecules / intermolecular | 1 |

08. 0620_w17_ms_42 Q: 5

| | | |
|---|---|---|
| (a) | both colours referred to correctly as observations in both parts of the answer | 1 |
| | (if sulfuric acid is added to solution **Y**,) equilibrium moves to the right-hand side | 1 |
| | because the concentration of acid has increased | 1 |
| | (if sodium hydroxide is added to solution **Y**,) equilibrium moves to the left-hand side | 1 |
| | because sodium hydroxide reacts with / neutralises sulfuric acid | 1 |
| (b)(i) | 210 $cm^3$<br>**M1** expected volume of hydrogen = 300 $cm^3$<br>**M2** 70% of **M1** | 2 |
| (b)(ii) | fewer moles / molecules / particles (of gas) on the left-hand side | 1 |
| (b)(iii) | endothermic | 1 |
| (b)(iv) | increases rate (of reaction) | 1 |

09. 0620_p16_ms_40 Q: 7

**(a)** rates equal; [1]
concentrations do not change / macroscopic properties remain constant; [1]

**(b)** endothermic **and** because this direction is favoured by high temperatures; [1]
note: reason is required

**(c)** **(i)** move to left hand side / reactants favoured **and** because bigger volume / more moles on left hand side [1]
note: reason is required

**(ii)** less (yellow) solid / more (dark brown) liquid / green gas visible / turns darker brown / smell chlorine [1]
allow: ecf from **(c)(i)**

**(d)** (bond breaking =) 151 + 242 = 393; [1]
(bond making =) 208 × 2 = –416; not: 416 [1]
(overall =) 393 – 416 = –23; allow: ecf [1]
note: sign must be given



**(e)** Any two from:
diagram shows exothermic reaction;
activation energy shown;
reactants and products labelled / both axes labelled;
note: labelling is one mark only
allow: ecf from **(d)** [2]

10. 0620_w16_ms_41 Q: 2

| | | |
|---|---|---|
| (a)(i) | melt(ing) | 1 |
| (a)(ii) | sublimation / sublime | 1 |
| (a)(iii) | condensing / condensation | 1 |
| (b) | overcome / break the attractive forces | 1 |
| (c) | **E AND** particles hit the walls (of the container) more often | 1 |

11. 0620_s14_ms_32 Q: 5

**(a) (i)** incomplete combustion **or** limited oxygen / less oxygen / not enough oxygen (1) [1]

**(ii)** any **two** from:

(forward) reaction is endothermic (1)

high temperature increases yield / favours forward reaction / shifts equilibrium to right (1)

faster reaction (rate) (1) [2]

**(iii)** any **two** from:

high pressure reduces yield **or** favours LHS (1)

because LHS has smaller volume **or** number of moles / number of molecules (of gas) ORA (1)

(high pressure plant is) expensive / dangerous / explosion / leaks [2]

**(b)** hydrogen **and** chlorine / $H_2$ **and** $Cl_2$ (1)

sodium hydroxide / NaOH / $Na^+OH^-$ (1)

$2H^+ + 2e \rightarrow H_2$ / $2H^+ \rightarrow H_2 - 2e$ (1)

$2Cl^- \rightarrow Cl_2 + 2e$ / $2Cl^- - 2e \rightarrow Cl_2$ (1)

Hydrogen / $H_2$ / H / $H^+$ at cathode **and** chlorine / chloride / $Cl_2$ / Cl / $Cl^-$ at anode (1) [5]

**(c)** each chlorine 1 bond pair and 3 non-bond pair (1)

oxygen atom 2 non-bond pairs and 2 bond pairs as double bond (1)

carbon atom 4 bond pairs including 2 bond pairs as double bond (1) [3]

[Total: 13]



---

12. 0620_w14_ms_33 Q: 2

**(a) (i)** (X(s) ↔) X(l) [1]

**(ii)** melting point/freezing point (of X) [1]

**(iii)** gas/gaseous or vapour [1]

**(iv)** not horizontal **or** line slopes **or** line is lower [1]

**(b) (i)** 14.3 [1]

**(ii)** 85.7 ÷ 12 and 14.3 ÷ 1 **or** 7.14 and 14.3 [1]
ratio 1:2 [1]
$CH_2$ [1]
**note:** Award all 3 marks for correct answer
**allow:** alternative working e.g.
85.7 × 84 ÷ 100 and 14.3 × 84 ÷ 100 **or** 71.988/72 and 12/12.012 [1]
6:12 **or** ratio 1:2 [1]
$CH_2$ [1]

**(iii)** $C_6H_{12}$ [1]

[Total: 9]

---

13. 0620_s13_ms_32 Q: 4

**(a) (i)** **first reaction**
volume / moles / molecules of reactants and products are different [1]

**second reaction**
volume / moles / molecules of reactants and products are the same [1]

**(ii)** first reaction (forward) reaction is endothermic [1]
second reaction (forward) reaction is exothermic [1]

**(b) (i)** $C_8H_{18} \rightarrow 2C_4H_8 + H_2$ [1]

**(ii)** $2H^+ + 2e \rightarrow H_2$ [2]

or $2H_3O^+ + 2e \rightarrow H_2 + 2H_2O$
**accept:** –2e on right hand side accept: $e^-$
**note:** not balanced = 1

**(iii)** chlorine / $Cl_2$ / [1]
**cond:** water treatment / solvents / plastics / PVC / bleach / disinfectants / HCl / kill bacteria / sterilising water / chlorination of water / swimming pools / pesticides / herbicides / insecticides / germicides / pharmaceuticals [1]

sodium hydroxide/NaOH [1]

**cond:** making soap / degreasing / making paper / detergents / bio-diesel / paint stripper / clearing drains / alumina from bauxite / oven cleaner / bleach [1]

---

14. 0620_w13_ms_31 Q: 3

**(a) (i)** fractional distillation [1]
(liquid) air [1]

**(ii)** cracking / heat in presence of catalyst [1]
of alkane / petroleum [1]
to give an alkene and hydrogen [1]

**OR:** electrolysis (1)
named electrolyte (1)
hydrogen at cathode (1)

**OR:** from methane (1)
react water / steam (1)
heat catalyst (1)
only **ACCEPT:** water with methane **or** electrolysis

**(b) (i)** the pair with both graphs correct is C [1]
**NOTE:** mark **(b)(ii)** independent of **(b)(i)**

**(ii)** high pressure favours side with lower volume / fewer moles [1]
this is RHS / product / ammonia [1]
%$NH_3$ / yield increases as pressure increases [1]

the forward reaction is exothermic [1]
exothermic reactions favoured by low temperatures [1]
%$NH_3$ / yield decreases as temperature increases [1]
**ACCEPT:** reverse arguments

**(iii)** increases reaction rate [1]
**ACCEPT:** reduces activation energy [1]
**OR:** decreases the amount of energy particles need to react
**OR:** economic rate at lower temperature so higher yield

**[Total: 14]**