WJEC Chemistry A-level

C2.4: The Wider Impact of Chemistry

Practice Questions

England Specification

1. (a) Planners have to ensure a secure supply of energy in the future. It has been suggested that the use of fossil fuels should be reduced, the use of renewable energy increased and that energy efficiency should be greatly improved.

By considering both the benefits and the difficulties involved, discuss whether you think that these suggestions are realistic.

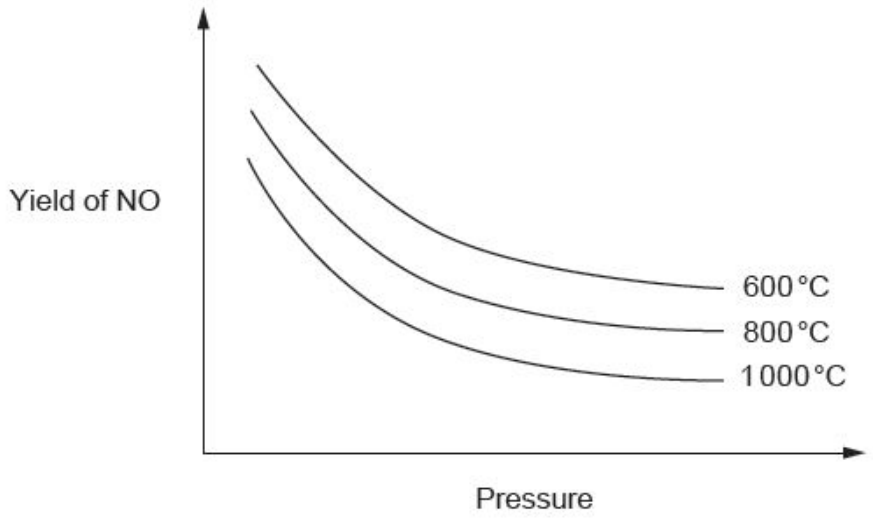
[4] QWC [1]

(b) Nitric acid is produced by the Ostwald process.

The first stage involves the oxidation of ammonia over a platinum/rhodium catalyst.

$$\text{ammonia} + \text{oxygen} \rightleftharpoons \text{nitric oxide} + \text{water}$$

The graph below shows how the yield of nitric oxide, NO, depends on the temperature and pressure used in its production.



(i) I. State the general variations in this yield with temperature and pressure

[1]

II. Use the graphs to explain whether the reaction is endothermic or exothermic and whether there are more moles of gaseous products than reactants.

[4] QWC [1]

(ii) Normally the process is carried out at a temperature of around 900 °C.

Suggest why this temperature is used.

[2]

(iii) State the **type** of catalyst used.

[1]

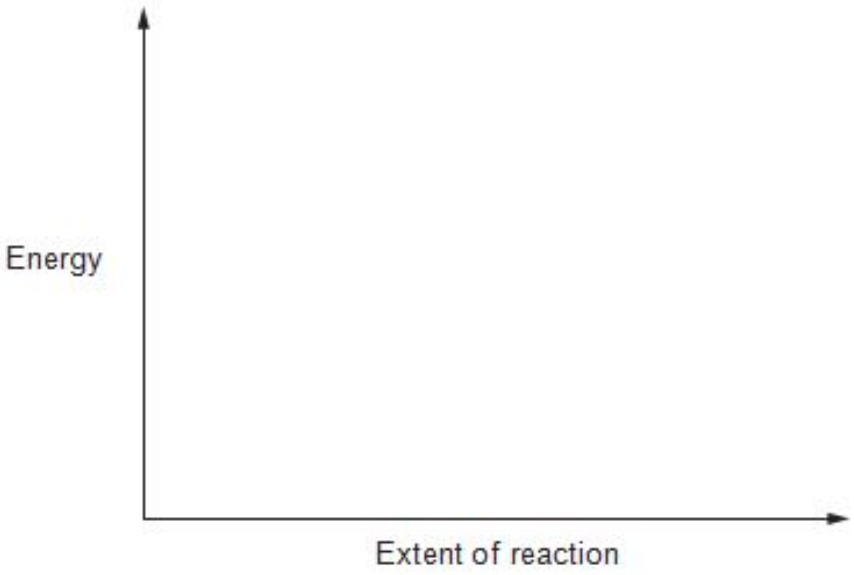
(iv) Explain why there has been much research to find a better catalyst.

[2]

(v) The next stage in the Ostwald process is to convert the nitric oxide to nitrogen dioxide.

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g) \qquad \Delta H = -114 \text{ kJ mol}^{-1}$$

Sketch on the axes below the energy profile for this reaction, clearly labelling the enthalpy change of reaction, ΔH. [2]



(vi) Write an expression that connects the enthalpy change of a reaction, ΔH, with the activation energies of the forward (E_f) and reverse (E_b) reactions. [1]

Total [19]

2. Hydrocarbons play an important role in our life today, both as fuels and as raw materials for the synthesis of a wide range of materials. Most hydrocarbons are isolated from crude oil, however there is increasing interest in alternative methods of obtaining these molecules.

(a) One route to the production of hydrocarbons is the Fischer-Tropsch process, which uses hydrogen and carbon monoxide as starting materials to produce a range of molecules. The equation below shows the production of pentane, C_5H_{12}, by this route.

$$11H_2(g) + 5CO(g) \longrightarrow C_5H_{12}(l) + 5H_2O(l) \qquad \Delta H^{\ominus} = -1049\,kJ\,mol^{-1}$$

The enthalpies of formation of some of these substances are given in the table below.

Substance	Standard enthalpy of formation, $\Delta H_f^{\ominus}$ / kJ mol^{-1}
Hydrogen, $H_2(g)$	0
Carbon monoxide, CO(g)	–111
Water, $H_2O(l)$	–286

(i) State the temperature and pressure used as standard conditions. Give units for each. [2]

Temperature ..... *Pressure* .....

(ii) State why the standard enthalpy of formation for hydrogen gas is 0 kJ mol^{-1}. [1]

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(iii) Use the values given to calculate the standard enthalpy of formation for pentane, $C_5H_{12}(l)$, in kJ mol^{-1}. [3]

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(b) The Fischer-Tropsch process uses a heterogeneous catalyst containing iron.

(i) State what is meant by the term *heterogeneous* in this context. [1]

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.....

(ii) Explain how a catalyst increases the rate of a chemical reaction. [2]

.....

.....

(iii) Chemical manufacturers consider catalysts to be a key part of production methods that have the minimum possible effect on the environment ('Green Chemistry'). Give **one** reason why the use of catalysts reduces the effect on the environment.[1]

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(iv) An alternative method of increasing the rate of a chemical reaction is to increase the temperature. Explain why temperature affects the rate of a chemical reaction. [3]
QWC [1]

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.....

(c) One method of producing the hydrogen gas required for the Fischer-Tropsch process is to use the reversible reaction below.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -42\,kJ\,mol^{-1}$$

(i) State and explain the effect, if any, of increasing pressure on the yield of hydrogen gas produced at equilibrium. [2]

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(ii) State and explain the effect, if any, of increasing temperature on the yield of hydrogen gas produced at equilibrium. [2]

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.....

(iii) This reaction uses a catalyst based on iron oxide. State the effect of using a catalyst on the position of equilibrium. [1]

.....

Total [19]

3. (a) The combustion of fossil fuels containing sulfur impurities is known to cause acid rain. This acid rain can cause the erosion of marble statues as the calcium carbonate in them reacts with the acid in the rain.

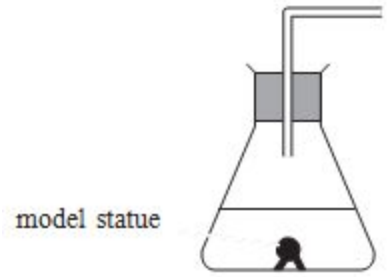
Give **one** other problem caused by acid rain.

[1]

(b) A chemist is developing coatings for marble that will slow down the rate of their erosion by acid rain. To compare different coatings he uses small model statues, all of which are the same size and shape as each other. He proposes to measure the rate of reaction by adding acid and measuring the volume of gas given off at set time intervals.

(i) Complete the diagram to show the apparatus that could be used to perform this experiment.

[1]



(ii) Explain why it is important that the model statues are the same size and shape as each other

[1]

(ii) State **two** other factors he will need to keep constant if he is to collect valid data.

[2]

(c) One gas that causes acid rain is sulfur dioxide. This gas is used to produce sulfur trioxide in the Contact Process. The reaction occurring is shown in the following equation.

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

(i) State and explain the effect of increasing pressure on the equilibrium yield of sulfur trioxide.

[2]

(ii) When the temperature is increased the rate at which equilibrium is reached is increased and the yield of sulfur trioxide is decreased.

I State whether this reaction is endothermic, exothermic or neither, giving a reason for your answer.

[2]

II Explain why increasing the temperature leads to an increase in the rate of reaction.

[3]

III To increase the rate of a reaction, a catalyst can be used. Give a **different** catalysed reaction and name the catalyst for this reaction.

[1]

(d) Ethanoic acid, CH_3COOH, is one of the most familiar compounds used as a flavouring and preservative for food. Originally ethanoic acid was produced by oxidation of ethanol by bacteria in the presence of air (route **A** below). Today there are many other possible routes and three of these are shown as routes **B**, **C** and **D** below.

Route	Carbon-containing starting materials	Conditions	Overall equation	Atom economy
A	ethanol		$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$	76.9%
B	methanol, carbon monoxide	150 °C, 30 atm	$CH_3OH + CO \rightleftharpoons CH_3COOH$	100.0%
C	butane	150 °C, 55 atm	$2C_4H_{10} + 5O_2 \rightarrow 4CH_3COOH + 2H_2O$	87.0%
D	sugars		$C_6H_{12}O_6 \rightarrow 3CH_3COOH$	

(i) State the atom economy of route **D** for production of ethanoic acid.

[1]

(ii) Route **B** is the route most commonly used for producing ethanoic acid today for both financial and *Green Chemistry* reasons. Apply the principles of *Green Chemistry* to the information above to give **two** reasons why route **B** is favoured over route **C**.

[2]

1. _____

2. _____

(iii) Route **B** uses a homogeneous catalyst. State what effect the catalyst will have on the position of this equilibrium.

[1]

(Total 17)

4. (a) The vast majority of motor vehicles worldwide are powered by petrol or diesel which come from crude oil. Give **two** reasons why we cannot rely indefinitely on oil as a source of transport fuel.

[2]

(b) Many vehicle manufacturers around the world have made the development of alternative fuels a priority. One such fuel being studied is hydrogen.

Its main advantage is that the only waste product is water, however hydrogen does not occur naturally on Earth. It is produced by passing an electric current through water.

(i) A leading car manufacturer said:

"Cars powered by hydrogen will be pollution-free"

Give **two** reasons why this is not necessarily true.

[2] QWC [1]

(ii) A spokesperson for a safety group said,

"Hydrogen can burn explosively. It must not be used in cars unless it is 100 % safe".

State, giving a reason, whether you agree with this.

[1]

(c) The first line in the visible atomic emission spectrum for hydrogen has a wavelength of 656 nm, while that for helium has a wavelength of 707 nm.
State, giving a reason, which line has:

(i) the higher frequency,

[1]

(ii) the higher energy.

[1]

(d) The first ionisation energy of helium is 2370 kJ mol^{-1} while that of neon is 2080 kJ mol^{-1}.
Explain why neon has a lower first ionisation energy than helium.

[2]

(e) Another noble gas is radon. Its more stable isotope ^{222}Rn has a half-life of 3.8 days, decays by α-emission and is responsible for the majority of the public exposure to ionising radiation.

(i) Give the symbol and mass number of the atom formed by the loss of one α-particle from an atom of ^{222}Rn.

[1]

(ii) Explain why doctors are concerned that an over-exposure to radon may cause lung cancer.

[1]

(Total 12)

5. *(a)* Nitrogen(I) oxide is a colourless gas that reacts with hydrogen to give nitrogen and water.

$$N_2O(g) + H_2(g) \longrightarrow N_2(g) + H_2O(l) \qquad \Delta H = -368 \text{ kJ mol}^{-1}$$

(i) State why the standard enthalpy of formation of both hydrogen and nitrogen gases is 0kJ mol^{-1}. [1]

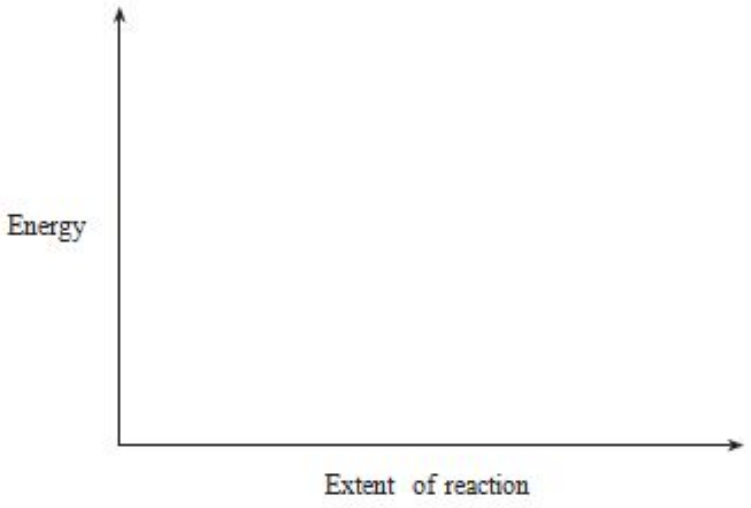
(ii) Calculate the standard enthalpy of formation of nitrogen(I) oxide in kJ mol^{-1}. (You should assume that the standard enthalpy of formation of water is –286kJ mol^{-1}) [2]

Standard enthalpy of formation = ... kJ mol^{-1}

(b) A new method for producing phenol, C_6H_5OH, is by reacting benzene, C_6H_6, with nitrogen(I) oxide at 400 °C in the presence of a suitable catalyst.

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2 \qquad \Delta H = -286 \text{ kJ mol}^{-1}$$

(i) Sketch the energy profiles for the catalysed and uncatalysed reactions using the axes shown below.
Label your profiles as *catalysed* and *uncatalysed*. [2]



(ii) A pilot-scale plant used 156 kg of benzene (M_r = 78) to produce phenol (M_r = 94).

I Calculate the number of moles of benzene used. [1]

Moles of benzene = ... mol

II The yield of phenol was 95 %. Using your answer to I and the equation below (or another suitable method), calculate the mass of phenol obtained. Show your working. [3]

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2$$

Mass of phenol = ... kg

(iii) Study the short account below, which gives more detail about this process.

The process to make phenol is carried out in the gas phase and uses a solid zeolite catalyst. The operating temperature is around 400 °C.

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2 \qquad \Delta H = -286 \text{ kJ mol}^{-1}$$

The reactants are the hydrocarbon benzene and nitrogen(I) oxide, which is a potent greenhouse gas. The nitrogen(I) oxide is obtained from another process, where it is produced as an undesirable side product.

Use the account and the equation to comment on the environmental and *Green Chemistry* advantages of this process. A reference to the yield is not required. [4]
QWC [1]

Total [14]

6.

(a) Potassium hydroxide contains potassium ions, K^+.
Give the electron configuration of a potassium **atom** and use this to explain why most potassium compounds contain the potassium ion. [2]

(b) Michael was asked to make 250 cm^3 of a solution of potassium hydroxide and to record the maximum rise in temperature that occurred as it dissolved.
He measured 250 cm^3 of water in a glass beaker and then added 7.01 g (0.125 mol) of solid potassium hydroxide to this, with stirring.
He noticed that the temperature rose from 20.2 °C to a maximum of 25.0 °C.

(i) Calculate the molar enthalpy change of solution of potassium hydroxide by use of the formula

$$\Delta H = -\frac{mc\Delta T}{n}$$

where m = mass of the solvent in grams (assume 1 cm^3 has a mass of 1 g)
c = 4.2 $J\,g^{-1}\,°C^{-1}$
ΔT = change in temperature of the solution
n = number of moles of the solute
ΔH = molar enthalpy change of solution

You should show the **units** in your answer. [3]

ΔH = ...

(ii) Michael's measurements produced a value for the enthalpy of solution of potassium hydroxide that was different to the literature value.

Use the information given to suggest and explain **two** factors that might produce a different result.

[2]

1. .....
.....

2. .....
.....

(c) Solid potassium hydroxide can be used in analysis to find the percentage of carbon dioxide present in a mixture of gases. The equation for the reaction that occurs is given below.

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$$

$2.0\,m^3$ of a gas mixture was passed through potassium hydroxide. Analysis showed that 1.50 mol of potassium carbonate had been formed.

(i) State the number of moles of carbon dioxide necessary to produce 0.050 mol of potassium carbonate. [1]

(ii) Calculate the volume of carbon dioxide that produced 0.050 mol of potassium carbonate. [1]

[1 mol of carbon dioxide has a volume of $24.0\,dm^3$ under these conditions]

Volume of carbon dioxide = ... dm^3

(iii) Calculate the percentage of carbon dioxide in the gas mixture, in terms of volume. [2]

[$1\,dm^3 = 0.001\,m^3$]

(d) Scientists have commented that 'an increase in the amount of carbon dioxide dissolved in seawater will cause problems for animals whose shells are composed of calcium carbonate'.

$$CO_2(aq) + H_2O(l) + CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq)$$

Use the equation above to help you discuss the problem that is caused for these animals by this increase in carbon dioxide concentration.

[3] QWC [1]

(Total 15)

7.

(a) State what is meant by the term *standard molar enthalpy change of formation*. [2]

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(b) (i) Write an equation to represent the standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$. [1]

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(ii) The standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$ is −242 kJ mol^{-1}. Using this value and the average bond enthalpies given in the table below, calculate the average bond enthalpy of the O—H bond in H_2O. [2]

Bond	Average bond enthalpy / kJ mol^{-1}
H—H	436
O=O	496

(c) Hydrogen has been proposed as a possible alternative to petrol as a fuel for cars. One suggestion is to store the hydrogen in the car as solid magnesium hydride, MgH_2, and generate it as required by heating.

(i) I Give **one** advantage of using hydrogen in place of petrol as a fuel for cars. [1]

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.....

II Give **one** advantage of storing the fuel in the car in the form of magnesium hydride rather than hydrogen gas. [1]

.....

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(ii) One possible disadvantage of using magnesium hydride arises from its reaction with water.

$$MgH_2(s) + 2H_2O(l) \longrightarrow Mg(OH)_2(s) + 2H_2(g)$$

Suggest why magnesium hydride's reaction with water could be a problem. [1]

.....

.....

(iii) The fuel tank of one type of hydrogen-powered car holds 70 kg of magnesium hydride.
Calculate the volume of hydrogen gas, measured at room temperature and pressure, which would be produced if this amount of magnesium hydride reacted with water. [3]
[1 mol of gas molecules occupies 24 dm^3 at room temperature and pressure]

Volume of hydrogen gas = ... dm^3

(d) Methanol can be produced industrially by passing carbon monoxide and hydrogen over a catalyst at high temperatures and pressures.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

(i) State how the equilibrium yield of methanol is affected by an increase in temperature and in pressure.

[1]

(ii) Explain your answer to part (i).

[2]

(e) Many catalysts are very expensive but their use does allow the chemical industry to operate more profitably. Explain why the use of catalysts provides economic and environmental benefits.

[3] QWC [1]

(Total 18)