CHEMISTRY
2008 TEE SOLUTIONS*

*THESE SOLUTIONS ARE NOT A MARKING KEY.
THEY ARE A GUIDE TO THE POSSIBLE ANSWERS
AT A DEPTH THAT MIGHT BE EXPECTED
OF YEAR 12 STUDENTS. IT IS UNLIKELY
THAT ALL POSSIBLE ANSWERS TO THE QUESTIONS
ARE COVERED IN THESE SOLUTIONS.

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Leadership in Science Education

PART 1 (60 Marks)

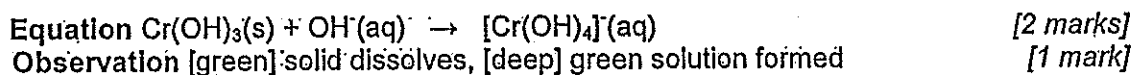| 1.	b	11.	a	21.	c
2.	c	12.	b	22.	b
3.	c	13.	a	23.	b
4.	c	14.	a	24.	d
5.	c	15.	b	25.	d
6.	a	16.	a	26.	b
7.	c	17.	a	27.	c
8.	d	18.	c	28.	d
9.	d	19.	d	29.	a
10.	b	20.	a	30.	d

END OF PART 1

PART 2 (70 Marks)

1. *1 mark is deducted for each error in the equation. While state symbols are not required for full marks they are useful for working out observations. The bulk of the observations must be provided for the full mark. Observations in square brackets are acceptable alternatives to the observations given.*
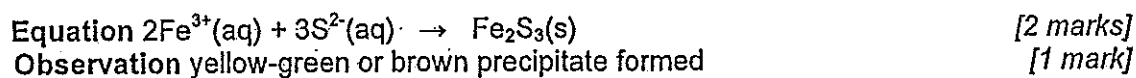
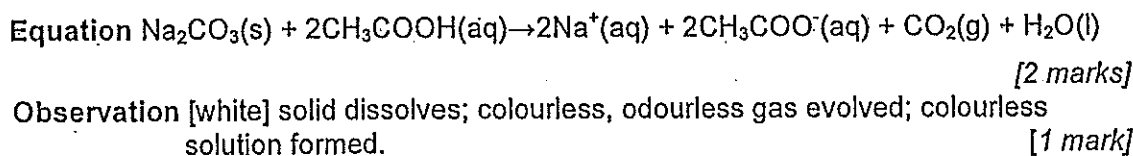(a) Chlorine gas is bubbled through a sodium iodide solution.

Equation $Cl_2 + 2I^- \rightarrow 2Cl^-(aq) + I_2(aq)$ *[2 marks]*
Observation [green] gas dissolves; colourless solution turns brown   *[1 mark]*

(b) Solid chromium(III) hydroxide is added to concentrated potassium hydroxide solution.

Equation $Cr(OH)_3(s) + OH^-(aq) \rightarrow [Cr(OH)_4]^-(aq)$ *[2 marks]*
Observation [green] solid dissolves, [deep] green solution formed   *[1 mark]*

(c) Iron(III) nitrate solution is added to sodium sulfide solution.

Equation $2Fe^{3+}(aq) + 3S^{2-}(aq) \rightarrow Fe_2S_3(s)$ *[2 marks]*
Observation yellow-green or brown precipitate formed   *[1 mark]*

(d) Solid sodium carbonate is added to an excess of acetic acid solution.

Equation $Na_2CO_3(s) + 2CH_3COOH(aq) \rightarrow 2Na^+(aq) + 2CH_3COO^-(aq) + CO_2(g) + H_2O(l)$
    [2 marks]
Observation [white] solid dissolves; colourless, odourless gas evolved; colourless solution formed.   *[1 mark]*

Note: Observations in square brackets are not required for full marks.

2.   *2 marks for each correct structural formula.*
      If lone pairs are incorrect in one or more of the three structures, subtract 1 mark overall.
      If charge or brackets missing subtract 1 mark overall.

Species	Electron dot diagram
Nitrogen gas	:N≡≡N:
Sodium nitrate	$[\text{Na}]^{+}$ $\left[\begin{array}{c} :\overset{..}{\underset{..}{O}}-N=\overset{..}{O}: \\ :\overset{..}{\underset{..}{O}}: \end{array}\right]^{-}$
Hydrazine, N_2H_4	$\text{H}-\overset{..}{\text{N}}-\overset{..}{\text{N}}-\text{H}$ with H below each N

[6 marks]

3.

1 mark for each use and related property.
If use does not relate to property 1 mark out of 2.
Any reasonable pair of answers is accepted. Examples are given.

Substance	Property	Related use
Magnesium	Easily oxidised Burns with bright white light Low density	Sacrificial anode Flash bulbs Alloys
Sodium hypochlorite	Strong oxidising agent	Bleaching agent Disinfectant Anti-bacterial cleaner
Aluminium	Low density Produces protective oxide layer Good conductor of electricity Good conductor of heat Highly reflective	Alloys requiring light weight e.g. aircraft skins Window frames etc Wires Cooking utensils Mirrors
Gold	Unreactive in air/remains shiney Excellent conductor Forms amalgams	Jewellery Electrical connectors Fillings

[8 marks]

4.   Menthone has dispersion and dipole-dipole forces between the molecules.

Menthol has dispersion forces and hydrogen bonding between the molecules.

As they are of similar size, the dispersion forces are of similar strength but hydrogen bonding is stronger than dipole-dipole, therefore more energy is required to break the bonds and so the melting point of menthol is higher.

[3 marks]

[1 mark per point]

5.   *1 mark for each correct answer. Any reasonable test accepted.*

Substances	Chemical Test	Expected observations
Cyclohexane (C_6H_{12}) and cyclohexene (C_6H_{10})	Add bromine water Or Add $KMnO_4(aq)$	C_6H_{12} No immediate change
		C_6H_{10} Brown solution turns colourless Purple solution decolourises
1 mol L^{-1} sulfuric acid solution (H_2SO_4) and 1 mol L^{-1} hydrochloric acid solution (HCl)	Add $BaCl_2(aq)$	H_2SO_4 White precipitate produced
		HCl No visible reaction
Propanone (CH_3COCH_3) and propanal (CH_3CH_2CHO)	Add small amount of acidified $KMnO_4(aq)$ or $K_2Cr_2O_7(aq)$	CH_3COCH_3 No visible reaction
		CH_3CH_2CHO Purple solution turns colourless or orange solution turns green,

[9 marks]

[1 mark per correct response]
For last substance pair – must be acidified, if not acidified observation is brown solid.

6.

$$K = \frac{[[Ag(NH_3)_2]^+][Cl^-]}{[NH_3]^2}$$ (also accept round brackets and K= missing)
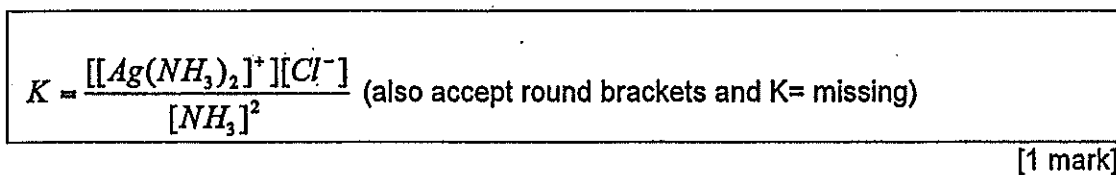
| Imposed change | At new equilibrium | | Observation |
	Effect on reaction rate	Effect $[Ag(NH_3)_2]^+$(aq)	
NH_3(g) is bubbled through the solution.	Increase	Increase	Some solid dissolves
$NaCl$ (s) is added to the solution.	Increase	Decrease	More solid forms
A few drops of concentrated HNO_3(aq) are added to the solution.	Decrease	Decrease	More solid forms

[1 mark each] Arrows are also accepted.

7.
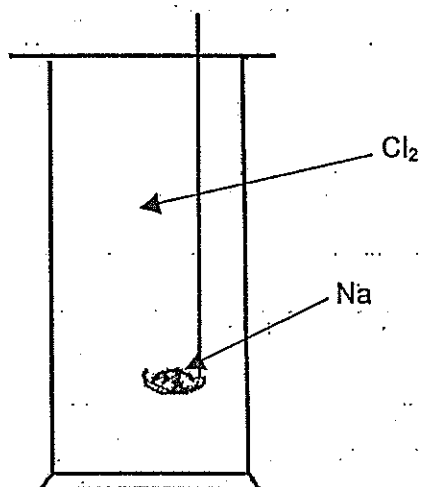
(a)

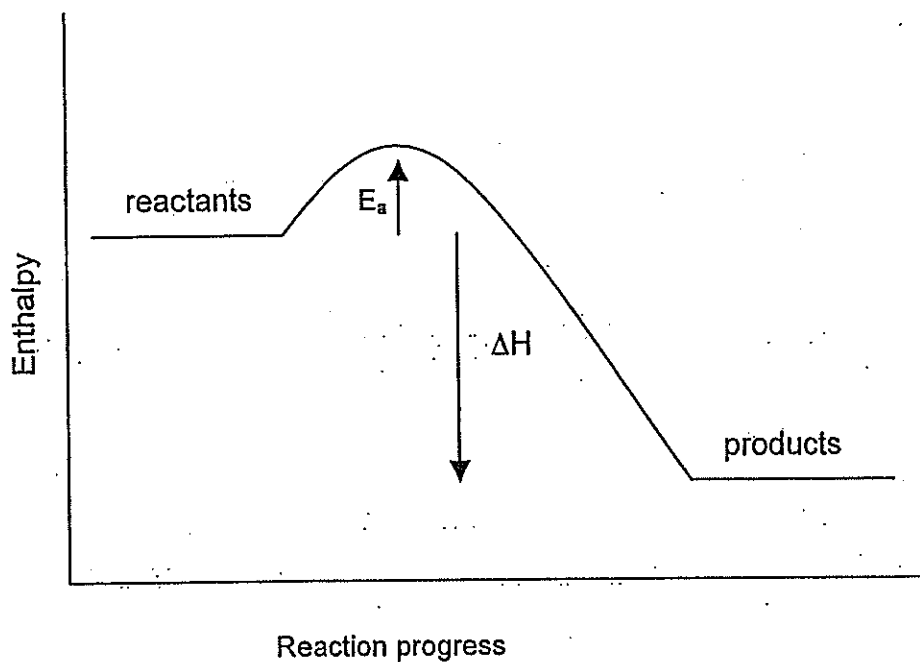(i)   activation energy of this reaction?

Small

(ii)   heat of reaction?

Large

[1 mark each]

(b)   1 mark for shape of curve (showing exothermic and small E_a)
1 mark for axes (Energy, Potential energy, Reaction coordinate and time acceptable)
1 mark for E_a and ΔH labelled correctly
Pay follow through on marks if error in a)

Reaction progress

(c)   The white powder produced from this reaction dissolved readily when added to distilled water. This solution is shown to conduct an electric current. Explain how the process of dissolving enables this solution to conduct electricity.

The white powder exists as ions in a fixed lattice. During dissolving the ions separate in solution.

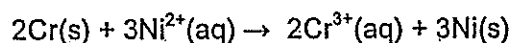The presence of mobile ions (charged particles) enables to the solution to conduct electricity.

[2 marks]

8.
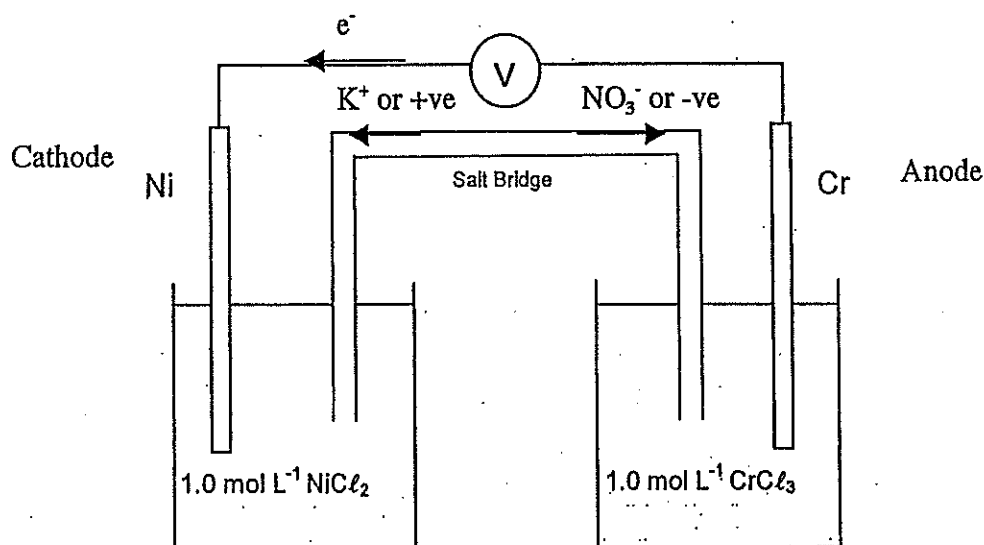
(a) Anode and cathode – 1 mark
Direction of electron flow – 1 mark
Direction of ions in salt bridge – 1 mark
No follow through

(b) Write an equation for the overall reaction in the cell.

$2Cr(s) + 3Ni^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Ni(s)$ [2 marks]

(c) Calculate the EMF (voltage) for the cell at standard conditions.

$-0.26 - (-0.73) = 0.47$ V   [1 mark]

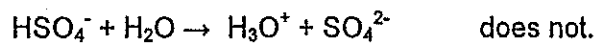(d) Why would a potassium carbonate salt bridge be an inappropriate choice for this electrochemical cell?

The carbonate ions would form a precipitate with the $Cr^{3+}(aq)$ and/or Ni^{2+} [1 mark].

9.   In HCℓ(aq) all of the molecules ionise, so that [H$^+$] = 0.200 mol L^{-1}.

For H_2SO_4, the first ionisation step

$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$ goes to completion.

The second ionisation step

$HSO_4^- + H_2O \rightarrow H_3O^+ + SO_4^{2-}$ does not.

Therefore the [H$^+$] ≠ 2 x 0.100 or 0.200 mol L^{-1}, it will be less, giving a higher pH than the HCℓ solution.

1 mark for equation/s
1 mark for explanation of HCℓ
2 marks for explanation of H_2SO_4

10.

2 marks each.
-1 overall if not two units shown
-1 overall if H atoms missing
-1 for each error otherwise
-2 if polymers correct but in wrong boxes
Square brackets not necessary

Addition polymer	
Condensation polymer	

END OF SECTION 2

PART 3 (50 Marks)

1 mark is deducted per question for inappropriate number of significant figures in final answers.

1.

(a)

$$V(O_2) = \frac{20.9}{100} \times 4.49 \times 10^6 = 9.384 \times 10^5 \text{ L}$$ 1 mark

$$n(O_2) = \frac{9.384 \times 10^5 (105.8)}{8.315(448)} = 2.653 \times 10^4 \text{ mol}$$ 1 mark

$$n(NH3) = \frac{457.3 \times 1000}{17.034} = 2.685 \times 10^4 \text{ mol}$$ 1 mark

Identification of limiting reagent (with supporting calculation) such as   2 marks

4 moles of NH_3 requires 5 moles of O_2

2.685 x 10^4 moles of NH_3 requires 5/4(2.685 x 10^4) = 3.356 x 10^4 mol of O_2

$n(O_2$ required) > $n(O_2$ available)

Therefore, O_2 is limiting reagent.

(b)

$n(NO) = 4/5(2.653 \times 10^4) = 2.12 \times 10^4$ mol   1 mark

$m(NO) = 2.12 \times 10^4(30.01) = 6.37 \times 10^5$ g   1 mark

(c)

$n(NH_3$ remaining) = 2.685 x 10^4 – 4/5(2.653 x 10^4) = 5.63 x 10^3 mol   1 mark

$m(NH_3) = 5.65 \times 10^3(17.034) = 9.59 \times 10^4$ g   1 mark

2.

(a)

$n(S_2O_3^{2-}) = 14.2(5.45) = 77.39$ mol   1 mark

$n(Cl_2) = 4(77.39) = 309.56$ mol   1 mark

$m(Cl_2) = 309.56(70.90) = 2.19 \times 10^4$ g   1 mark

(b)

2 marks

$[Cl_2] = \dfrac{2.19x10^4(1000)}{265} = 8.28 \times 10^4$ ppm

(c)

$n(H^+ + HSO_4^-) = 10n(S_2O_3^{2-}) = 10(77.39) = 773.9$ mol   2 marks

$n(OH^-) = 773.9$ mol   1 mark

$V(OH^-) = \dfrac{773.9}{6.88} = 112$ L   1 mark

3.

Titration Results	Trials (mL)			
	1	2	3	4
Final Volume	32.05	32.10	31.11	33.25
Initial volume	0.50	2.45	1.40	3.65
Titre	31.55	29.65	29.71	29.60

(a) $H_2C_2O_4 + 2OH^- \rightarrow C_2O_4^{2-} + 2H_2O$ [1 mark]

(b) See table above [1 mark]

(c)

$$V(OH^-) = \frac{29.65 + 29.71 + 29.60}{3} = 29.65 \text{ mL}$$ 1 mark

(d)

$n(OH^-) = 0.115(0.02965) = 3.41 \times 10^{-3} \text{ mol}$ 1 mark
$n(H_2C_2O_4) = \frac{1}{2}(3.41 \times 10^{-3}) = 1.71 \times 10^{-3} \text{ mol}$ 1 mark

$$[H_2C_2O_4] = \frac{1.71 \times 10^{-3}}{0.0200} = 8.53 \times 10^{-2} \text{ mol L}^{-1}$$ 1 mark

(e)

$$n(H_2C_2O_4 \text{ in } 250.0 \text{ mL}) = 1.71 \times 10^{-3} \times \frac{250}{20} = 0.0213 \text{ mol}$$ 1 mark

$m(H_2C_2O_4) = 0.0213(90.036) = 1.92 \text{ g}$

$$\% \text{ purity} = \frac{1.92}{2.05} \times 100 = 93.6 \%$$ 1 mark

(f) Phenolphthalein (or equivalent) [1 mark]
The equivalence point of the reaction is basic due to the production of a slightly basic salt (the oxalic acid ion is slightly basic) and the indicator changes in the basic range.
(or anything reasonable) [1 mark]

4.

(a)

$Q = 15.0(6.50 \times 60 \times 60) = 3.51 \times 10^5 \, C$ 1 mark

$n(e^-) = \dfrac{3.51x10^5}{9.649x10^4} = 3.64 \, mol$ 1 mark

$n(Pb) = \frac{1}{2} (3.64) = 1.82 \, mol$ 1 mark

$m(Pb) = 1.82 \times 207.2 = 377 \, g$ 1 mark

$m(Pb) = 377 \times 0.65 = 245 \, g$ (65% efficiency)   1 mark
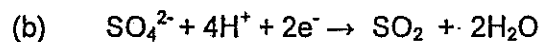
(b) $SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ [2 marks]
         -1 for each error

(c)

$n(e^-) = 0.014(3.64) = 5.09 \times 10^{-2} \, mol$ 1 mark

$n(SO_2) = \frac{1}{2} (5.09 \times 10^{-2}) = 2.5 \times 10^{-2} \, mol$ 1 mark

$P(SO_2) = \dfrac{2.52x10^{-2}(8.315)(301)}{0.300} = 2.12 \times 10^2 \, kPa$ 1 mark

5. There are two methods commonly used in this type of calculation. Both are given here.

(a)

$$n(CO_2) = \frac{6.32}{44.01} = 0.1436 \text{ mol}$$ 1 mark

$$\% \ C = \frac{0.1436 \times 12.01}{5.21} \times 100 = 33.10 \ \%$$ 1 mark

$$n(H) = 2 \times \frac{3.23}{18.016} = 0.361$$ 1 mark

$$\% \ H = \frac{0.361 \times 1.008}{5.21} \times 100 = 6.937 \ \%$$ 1 mark

$$3Ca^{2+} + 2PO_4^{3-} \rightarrow Ca_3(PO_4)_2$$ 1 mark

$$n(P) = 2n(Ca_3(PO_4)_2) = \frac{2 \times 3.37}{310.18} = 0.0217 \text{ mol}$$ 1 mark

$$\% \ P = \frac{0.0217 \times 30.97}{3.15} \times 100 = 21.36 \ \%$$ 1 mark

$$\% \ O = 100 - (33.10 + 6.93 + 21.36) = 38.61 \ \%$$ 1 mark

	C	H	P	O	1 mark
m in 100 g	33.10	6.937	21.36	38.61	
n	2.756	6.882	0.6897	2.413	

Divide by smallest n 1 mark

X 2, $C_8H_{20}P_2O_7$ 1 mark

(b)

$$EFM = 290.18, \therefore EF = MF, C_8H_{20}P_2O_7$$ 1 mark

Second Method

(a) Method using proportions

$$n(CO_2) = \frac{6.32}{44.01} = 0.1436 \text{ mol}$$ 1 mark

$$m \ (C) = 0.1436 \times 12.01 = 1.725 \ g$$ 1 mark

$$n(H) = 2 \times \frac{3.23}{18.016} = 0.361 \text{ mol}$$ 1 mark

$$m(H) = 0.361 \times 1.008 = 0.3639 \ g$$ 1 mark

$$3Ca^{2+} + 2PO_4^{3-} \rightarrow Ca_3(PO_4)_2$$ 1 mark

$$n(P) = 2n(Ca_3(PO_4)_2) = \frac{2 \times 3.37}{310.18} = 0.0217 \text{ mol}$$ 1 mark

$$m(P) = \frac{0.0217 \times 5.21 \times 30.97}{3.15} = 1.11 \ g$$ 1 mark

$$n(O) = \frac{5.21 \ (1.725 + 0.3639 + 1.11)}{16} = 0.126 \text{ mol}$$ 1 mark

	C	H	P	O	1 mark
n	0.1436	0.361	3.59×10^{-2}	0.126	

Divide by smallest n 1 mark

X 2, $C_8H_{20}P_2O_7$ 1 mark

PART 4 (20 Marks)

In general for full marks an essay should be a minimum of 1 ½ to 2 pages and
- *Demonstrate sound understanding of chemistry*
- *On the topic given*
- *Written in reasonable English*
- *With some reasoning shown*
- *With a beginning, middle and end*
- *Either no errors, or errors which are trivial.*

As there are two parts to this question, students must address both parts to be eligible for full marks. Students may focus on either part to a greater extent than the other. The suggested mark breakdown is a maximum of 12 marks for the section answer provided in the greatest detail and 8 marks for the other section. A maximum of 6 marks can be awarded where students just describe the gold and aluminium processes in detail but do not relate them to the question. Students should be able to score full marks without describing all of the processes in detail (this has been specified in the question). Where an essay uses both gold and aluminium, mark the process that would give the student the best mark. No extra marks are to be awarded for using both processes.

While students may adopt a wide range of approaches to answering the question, some points are provided below of the sort of material that students should include for a good answer. The students must include some relevant equations for full marks. While diagrams would help an answer here, they are not required. This set of points is not meant to be comprehensive.

For comparison with Aluminium

In both methods a complex is produced.

Aluminium is in the form of an impure oxide (rather than sulphide) is reacted with hot, concentrated (saturated) NaOH. Students should include equations in the explanation.

As aluminium is amphoteric, the impurities do not react with the sodium hydroxide while the aluminium does. The nickel forms a complex while the other impurities do not. The nickel process involves gases and so a high pressure is used to increase rate and yield. The aluminium process is solution based so high temperatures and concentrations increase rate.

Both processes use electrolysis to recover the metal. Nickel can be electrolysed from an aqueous solution as it is more easily reduced than water and so can be carried out at a low/moderate temperature. As aluminium is less easily reduced than water a molten solution must be used (students may refer to the use of cryolite) and so the process must occur at a much higher temperature. The energy requirements for the electrolysis of aluminium are much higher than those of nickel.

For comparison with gold

In both methods a complex is produced.

Au exists in metallic form but is in low concentration in the ore. The addition of the CN⁻ and O_2 forms the complex. The reaction occurs at room temperature and addition of O_2. Students should include equations in their explanation.

Both metals are purified by electrolysis of aqueous solutions as they are both more easily reduced than water. The gold process involves a steel wool electrode as opposed the pure nickel cathode. The steel wool can be dissolved by reaction with acid solution which does not react with the gold. Nickel in the same circumstance would dissolve with the iron.

Mond Process

Step 1 goes to completion and so only rate factors need to be considered. This reaction, for faster rate, would require high temperature, high pressure and excess of hydrogen. As high temperatures and pressures are expensive it is probable that the moderate conditions give an economically viable rate.

High temperatures result in faster moving particles and therefore more collisions. This will increase the rate of the reaction, but is not the significant advantage to higher temperature. The second benefit of higher temperature is that more particles will now react with sufficient energy and so a greater proportion of the collisions between the particles will be successful giving a higher rate of reaction.

Higher partial pressures of all of the components mean there are more particles per unit area (or a higher concentration). A greater number of particles mean a greater number of particles. Although the percentage of successful collisions will not increase, the absolute number of successful collisions will resulting in a higher reaction rate.

Using an excess of hydrogen will have a similar impact to higher partial pressures. There will be a greater number of particles and so a greater number of successful collisions.

Step 2 is an exothermic reaction and so low temperatures would favour higher yield. A high pressure would also favour the products as well as an excess of carbon monoxide. For rate, high temperature, high pressure and excess of CO. As the temperature used is reasonably low, the excess CO and moderate pressures must produce a high enough rate.

The application of Le Chatalier's principle suggests that in order to increase the yield of an exothermic reaction, a low temperature is preferable (the system will favour the direction that counteracts the reduction in heat energy).

For high pressure, the system will favour the direction that reduces the pressure (which is directly proportional to the number of gas particles). In this reaction, the forming more products will reduce the overall number of gas particles and so the pressure will be reduced.

Adding more CO will favour the forward reaction rate over the reverse reaction rate until equilibrium is re-established. This will result in more products being formed.

Step 3 is the reverse reaction to step 2 and so high temperatures and low pressures would favour yield. High temperatures would favour rate. As the temperature used is much higher than the previous step, both yield and faster rate are favoured. Platinum is used as catalyst to increase rate. It will have no effect on yield.