

# Cl.a-k - The chemical industry | Cl1-6 |

## Cl.Q Exam questions from past papers

<p>The compounds of nitrogen given in the table are atmospheric pollutants. These can occur naturally or as a result of human activities.</p> <p>i. Give a natural source of NO in the atmosphere.</p> <p style="text-align: center;">[1]</p> <p>Give a natural source of NO in the atmosphere?</p>	<p>(Reaction of N<sub>2</sub> and O<sub>2</sub> during) lightning OR forest fires OR from bacterial processes OR photodissociation of NO<sub>x</sub>. AW. ✓</p>	<p>1 Examiner's Comments Not answered well which was surprising, as candidates would have covered this again in Agriculture and Industry (Nitrogen Cycle).</p> <ul style="list-style-type: none"> <li>● Lightning</li> <li>● Forest fires</li> <li>● From bacterial processes</li> <li>● Photodissociation of NO<sub>2</sub></li> </ul>										
<p>(iii) Describe a test that would identify nitrate ions.</p> <p>..... ..... ..... [2]</p> <p>Describe a test that would identify nitrate ions (2)</p>	<p>(iii) Add NaOH and Devarda's alloy or Al powder and warm ✓ Test gas with indicator paper/ red litmus/ rod dipped in HCl turns blue/ dense white fumes (due to ammonia) ✓</p>	<p>2 Reagents and heat needed Test and positive result for ammonia negative result for nitrate <b>ALLOW</b> Brown Ring Test (add Fe<sub>2</sub>SO<sub>4</sub> solution followed by conc H<sub>2</sub>SO<sub>4</sub>) - a brown ring forms at the layer interface</p> <ul style="list-style-type: none"> <li>● Add NaOH solution and devarda's alloy (or Aluminium foil)</li> <li>● Warm the solution</li> <li>● Test gas with red litmus paper and would turn blue if ammonia is present</li> <li>● [as the Al in both would reduce the nitrate ions]</li> </ul> <p>(You would see dense white fumes due to ammonia)</p> <p><i>Allow use rod dipped in HCl turns blue</i></p> <p><i>Allow Brown Ring Test (add Fe<sub>2</sub>SO<sub>4</sub> solution followed by conc H<sub>2</sub>SO<sub>4</sub>) - a brown ring forms at the layer interface</i></p>										
<p>Some students set out to investigate the rate of hydrolysis of 1-bromobutane. They mix 1-bromobutane with sodium hydroxide solution and measure the conc of hydroxide ions after certain times at 51 degrees?</p> <p>Suggest the procedure the students use to follow the reaction? (3)</p> <p>How did they maintain the temperature at 51 degrees (1)</p>	<ul style="list-style-type: none"> <li>● Quench the solution taking certain volume of solution at set intervals of time (1)</li> <li>● Cool down the samples in ice water (1)</li> <li>● Do a titration for each sample to find the concentration of hydroxide ions (1)</li> <li>● By using a water bath</li> </ul>											
<p>16</p> $2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2$ <p style="text-align: center;">Equation 4.1</p> <p>(e) A student suggests the following mechanism for the reaction in equation 4.1. The reaction is first order with respect to N<sub>2</sub>O<sub>5</sub>.</p> <p>N<sub>2</sub>O<sub>5</sub> → NO<sub>2</sub> + NO<sub>3</sub> step 1 NO<sub>3</sub> → O<sub>2</sub> + NO step 2 NO + N<sub>2</sub>O<sub>5</sub> → 3NO<sub>2</sub> step 3</p> <p>Show that this is a possible mechanism.</p> <p>Consider which step(s) could be rate-determining.</p> <p>..... ..... ..... ..... ..... [3]</p> <p>Consider which step is the rate-determining? (3)</p>	<p>(this is a possible mechanism because) reactions add to overall equation / 2N<sub>2</sub>O<sub>5</sub> → 4NO<sub>2</sub> + O<sub>2</sub> ✓</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px; width: 80%;">3</td> <td style="padding: 2px; width: 20%;">3.1 x 3</td> </tr> </table> <p style="text-align: right;">June 2011</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 40%;">Answer</th> <th style="width: 15%;">Marks</th> <th style="width: 15%;">AO element</th> <th style="width: 30%;">Guidance</th> </tr> </thead> <tbody> <tr> <td style="padding: 2px;">step 1 could be rate determining because it uses N<sub>2</sub>O<sub>5</sub> as a reactant / N<sub>2</sub>O<sub>5</sub> decomposes ✓ step 3 could be rate determining because it uses N<sub>2</sub>O<sub>5</sub> as a reactant / could be slow compared to steps 1 and 2 ✓</td> <td style="padding: 2px;"></td> <td style="padding: 2px;"></td> <td style="padding: 2px;">ALLOW cannot be step 2 as NO<sub>3</sub> does not appear in the equation for 1 mark if no reference made to either step 1 or step 3. <b>ALLOW BOTH</b> step 1 and step 3 could be RDS with a reason scores 2 marks <b>BOTH</b> step 1 and step 3 with no reason scores 1 mark</td> </tr> </tbody> </table> <ul style="list-style-type: none"> <li>● Reactions add to make overall equation (1)</li> <li>● Step 1 could be rate determining as it uses N<sub>2</sub>O<sub>5</sub> as a reactant (1)</li> <li>● Step 3 could be rate determining as it uses N<sub>2</sub>O<sub>5</sub> as a reactant (1)</li> </ul>	3	3.1 x 3	Answer	Marks	AO element	Guidance	step 1 could be rate determining because it uses N <sub>2</sub> O <sub>5</sub> as a reactant / N <sub>2</sub> O <sub>5</sub> decomposes ✓ step 3 could be rate determining because it uses N <sub>2</sub> O <sub>5</sub> as a reactant / could be slow compared to steps 1 and 2 ✓			ALLOW cannot be step 2 as NO <sub>3</sub> does not appear in the equation for 1 mark if no reference made to either step 1 or step 3. <b>ALLOW BOTH</b> step 1 and step 3 could be RDS with a reason scores 2 marks <b>BOTH</b> step 1 and step 3 with no reason scores 1 mark	
3	3.1 x 3											
Answer	Marks	AO element	Guidance									
step 1 could be rate determining because it uses N <sub>2</sub> O <sub>5</sub> as a reactant / N <sub>2</sub> O <sub>5</sub> decomposes ✓ step 3 could be rate determining because it uses N <sub>2</sub> O <sub>5</sub> as a reactant / could be slow compared to steps 1 and 2 ✓			ALLOW cannot be step 2 as NO <sub>3</sub> does not appear in the equation for 1 mark if no reference made to either step 1 or step 3. <b>ALLOW BOTH</b> step 1 and step 3 could be RDS with a reason scores 2 marks <b>BOTH</b> step 1 and step 3 with no reason scores 1 mark									

The students then set up some experiments to find the orders of reaction with respect to iodide and hydrogen ions.

At the starting time they mix the hydrogen peroxide, acid and iodide ions together with a fixed volume of sodium thiosulfate and starch solutions.

They measure the time for the colourless solutions suddenly to go dark blue as iodine is formed.

(i) Suggest why the tubes go dark blue after a period of time rather than gradually from the start.

1. Suggest why the tubes go dark blue after a period of time rather than gradually from the start. (3)
2. How can relative rates of reactions be found from the student's results?

- Thiosulfate reacts with the iodine until thiosulfate is used up

- Iodine reacts to form blue black colour with starch

thiosulfate reacts with the iodine until thiosulfate is used up ✓  
iodine (reacts to) form (blue/blue-black) colour with starch ✓

- $1/\text{time} = \text{rate}$

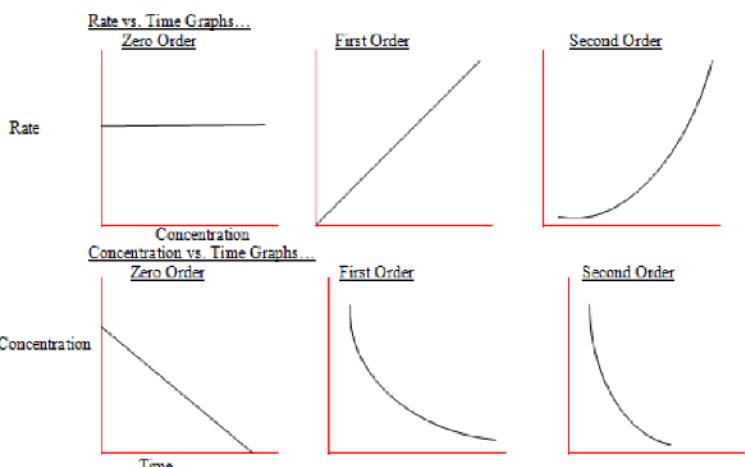
1/time ✓

1

3.3

## Cl.a-e - Kinetics | CI3 | CI4 | CI5 |

Define Rate of reaction?	<p>The change in concentration of a substance per unit time</p> <p><i>This is used for consistency as it's better than say change in mass per unit time</i></p>
Give 6 ways of determining the rate of reactions?	<ol style="list-style-type: none"><li>1. Use a gas syringe to measure the change in volume of gas</li><li>2. Use a top pan balance to measure the change in mass as gases escapes (works best with a heavy gas like <math>\text{CO}_2</math>)</li><li>3. Measure the time taken for a precipitate to form (cross method)</li><li>4. Use colorimetry to measure absorbance of a wavelength by a chemical</li><li>5. Chemical analysis by quenching and titration</li><li>6. Do a clock reaction</li></ol> <p><i>Also measure a change in electricity conductivity (works well if ions are released)</i></p>
What are the 3 orders of reaction with their associated rate-concentration and concentration-time graphs of the reactant(s)?	<ul style="list-style-type: none"><li>● Zero-order reaction - rate is not changed by concentration</li><li>● First-order reaction - rate <math>\propto</math> conc</li><li>● Second-order rate - rate <math>\propto</math> conc<sup>x</sup> (by some factor i.e if conc x2 then rate is x4)</li></ul>



*The concentration-time graph of a second-order reaction isn't required.*

Describe the following general rate equation:  $r = k[A]^x[B]^y$

- Based on the reaction...  $aA + bB \rightarrow \text{products}$
- Unit of  $r$  (rate) is  $\text{mol dm}^{-3}\text{s}^{-1}$ , unit of  $[A]$  and  $[B]$  (conc. of A and B) are  $\text{mol dm}^{-3}$ , and unit of  $k$  (rate constant) varies
- The rate constant is **ONLY** dependent on temperature (i.e., it increases with temperatures)
- The values  $x$  and  $y$  are called reaction orders and have nothing to do with the stoichiometric coefficients (moles) in the balanced equations.  
**They are worked out experimentally and can be 0,1 or 2**
- The overall order is  $x + y$

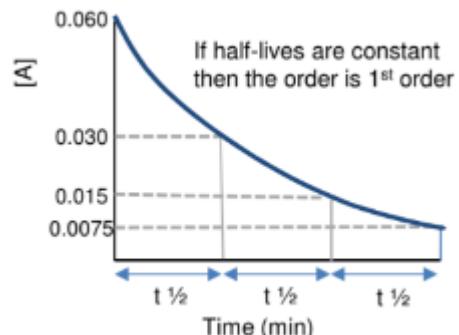
What is the half-life of a reaction? And the half-life equation for a first-order reaction?

- The time taken for the conc of a reaction to half (which is constant for a first-order reaction).
- Depending on the question find 3 half lives unless quoted otherwise
- The equation for first order is

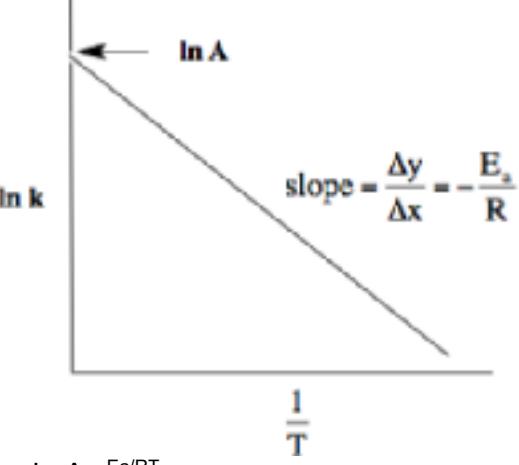
$$t_{1/2} = \frac{\ln 2}{k}$$

i.e graph:

- Shown on the graph:



*If the half-life rapidly increases then the reaction is*

	second-order. If the half-life decreases then it's zero-order.
Give 2 ways of determining orders of reaction and state the benefit of one over the other	<ol style="list-style-type: none"> <li>1. Use a clock reaction to get a good approximation of the initial rate</li> <li>• Then use the initial rates method</li> <li>2. Continually monitor [A] and form a concentration-time graph for many different concentrations then use this to plot a rate-concentration graph whose shape you can use.</li> </ol> <p><i>The first method is far less time-consuming as a graph doesn't have to be plotted each time</i></p>
What 3 assumptions are made during a clock reaction?	<ol style="list-style-type: none"> <li>1. The concentration of reactant doesn't change significantly over the timescale</li> <li>2. Constant temperature</li> <li>3. When the endpoint is observed, the reaction has not proceeded too far.</li> </ol> <p>This allows us to assume a constant rate</p>
What should be ensured when continually monitoring [A] and why? (in rates of reaction)	Having a large excess of everything else so their conc. Is effectively constant -> its conc won't change much during the reaction -> won't affect the reaction
How can you work out reaction orders using experimental initial rate and concentration data? [The script to experimental data rate questions!]	<ol style="list-style-type: none"> <li>1. You have some equation <math>r = [X]^a[Y]^b</math>. Comparing (1) and (2), the order of reaction w.r.t. [X] is 1 (as initial rate doubles when initial conc doubles)</li> <li>2. Comparing (2) and (3), both X and Y double whilst the initial rate increases x8. Know [X] is order 1 so Y doubling increases initial rate x4 -&gt; order 2</li> </ol> <p><i>Say you have <math>r = k[A][B]^2</math>. The effect of individual changes in conc are multiplied E.g., if [A] x 2 and [B] x 3 then initial rate x 18</i></p>
What is the Arrhenius equation both variations, what can it be used to find?	 <ul style="list-style-type: none"> <li>• <math>k = Ae^{-E_a/RT}</math></li> <li>• <math>\ln k = \ln A + -E_a/RT</math></li> <li>• <math>k = \text{rate constant (which is proportional to rate)}</math></li> <li>• <math>E_a = \text{activation energy in Jmol}^{-1}</math></li> </ul>

- $R$  = gas constant
- $T$  = temperature in K

In the form of  $y = mx + c$   
 $\ln k = (-E_a / R) x (1/T) + \ln A$

**Plot-Wise Approach** { 
$$\ln k = \left( \frac{-E_a}{R} \right) \cdot \left( \frac{1}{T} \right) + \ln A$$

Use to determine the activation energy using a set of temperature and rate constants. Can also be used to determine the frequency factor (A) which would

$$k = Ae^{-E_a/RT}$$

$$\ln k = \ln(Ae^{-E_a/RT})$$

$$\ln k = \ln A + \ln e^{-E_a/RT}$$

$$\ln k = \ln A + \frac{-E_a}{RT}$$

be the y intercept then times it by e

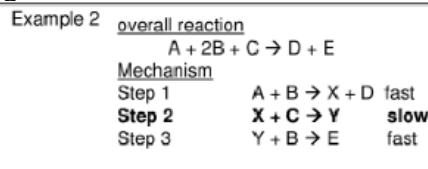
### Define Rate Determining Step (RDS)?

The slowest step in a reaction mechanism which determines the overall rate of reaction

What things should you look out for when proposing mechanisms from overall reactions and rate equations?

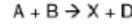
1. A catalyst appearing in the rate equation as it will reform later
2. When the slowest step contains an intermediate (not a reactant). It should be replaced by substances that make up the previous step

E.g.,



$r = k[X]^1[C]^1$

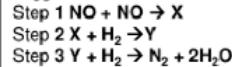
The intermediate X is not one of the reactants so must be replaced with the substances that make up the intermediate in a previous step



$r = k[A]^1[B]^1[C]^1$

Example 4

Using the rate equation rate =  $k[NO]^2[H_2]$  and the overall equation  $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$ , the following three-step mechanism for the reaction was suggested. X and Y are intermediate species.



Which one of the three steps is the rate-determining step?

Step 2 – as  $H_2$  appears in rate equation and combination of step 1 and 2 is the ratio that appears in the rate equation.

*You need both to be able to propose the mechanism*

What should you be aware of when suggesting a mechanism via a rate determination step through an

- $2N_2O_5 \rightarrow 4NO_2 + O_2$
- Even though there are 2 moles in the equation,

<p>example?</p>	<ul style="list-style-type: none"> <li>experimentally the reaction is 1st order w.r.t <math>\text{N}_2\text{O}_5</math></li> <li>Rate = <math>k[\text{N}_2\text{O}_5]</math></li> <li>This determines there is only 1 mole of <math>\text{N}_2\text{O}_5</math> in the RDS</li> <li>One possible mechanism is:</li> <li><math>\text{N}_2\text{O}_5 \rightarrow \text{NO}_2 + \text{NO}_3</math> - slow step</li> <li><math>\text{NO}_3 + \text{N}_2\text{O}_5 \rightarrow 3\text{NO}_2 + \text{O}_2</math> - fast</li> <li>1st step is RDS as there is 1 mole of <math>\text{N}_2\text{O}_5</math> and is the only equation with only rate equation reactants</li> </ul> <p><b>You have to Take Care when Suggesting a Mechanism</b></p> <p>If you're suggesting a mechanism, <b>watch out</b> — things might not always be what they seem. For example, when nitrogen(V) oxide, <math>\text{N}_2\text{O}_5</math>, decomposes, it forms nitrogen(IV) oxide and oxygen:</p> $2\text{N}_2\text{O}_{5(g)} \rightarrow 4\text{NO}_{2(g)} + \text{O}_{2(g)}$ <p>From the chemical equation, it looks like two <math>\text{N}_2\text{O}_5</math> molecules react with each other. So you might predict that the reaction is <b>second order</b> with respect to <math>\text{N}_2\text{O}_5</math>... but you'd be wrong. Experimentally, it's been found that the reaction is <b>first order</b> with respect to <math>\text{N}_2\text{O}_5</math> — the rate equation is:</p> $\text{rate} = k[\text{N}_2\text{O}_5]$ <p>This shows that there's only one molecule of <math>\text{N}_2\text{O}_5</math> in the rate-determining step. One possible mechanism that fits the rate equation is:</p> <p>Only one molecule of <math>\text{N}_2\text{O}_5</math> is in the rate-determining step, fitting in with the rate equation.</p> <p><math>\text{N}_2\text{O}_{5(g)} \rightarrow \text{NO}_{2(g)} + \text{NO}_{3(g)}</math> — slow (rate-determining step)</p> <p><math>\text{NO}_{3(g)} + \text{N}_2\text{O}_{5(g)} \rightarrow 3\text{NO}_{2(g)} + \text{O}_{2(g)}</math> — fast</p> <p>The two steps add up to the overall chemical equation. You can cancel the <math>\text{NO}_{3(g)}</math> as it appears on both sides.</p>
<p>What are 2 things that are always true for the rate determining step?</p>	<ul style="list-style-type: none"> <li>Only reactants in the rate equation is involved in RDS</li> <li>Order of reaction in rate equation (i.e. moles of reactant) = Moles in RDS</li> </ul>

## Cl.f-h - Equilibrium | Cl2 | Cl6 |

<p>What compromises must be made when altering the equilibrium position and why?</p>	<p><b>Pressure:</b></p> <ul style="list-style-type: none"> <li>A lower pressure when favouring the side with less moles <math>\rightarrow</math> high pressures are difficult to produce as high <b>costs</b> (high electrical costs in pumping gas) and is <b>unsafe</b> (difficult to contain high pressures)</li> <li>A higher pressure when favouring side with more moles otherwise the rate of reaction will be <b>too low</b>.</li> </ul> <p><b>Temperature:</b></p> <ul style="list-style-type: none"> <li>A higher temperature when favouring the exothermic side otherwise the rate of reaction will be <b>too low</b></li> <li>A lower temperature when favouring the endothermic side <math>\rightarrow</math> high <b>costs</b></li> <li>Because this allows for a compromise in the <b>rate of reaction and yield</b></li> </ul> <p><i>For either temp or pressure focus on talking about Costs, Safety, rate and yield for compromises</i></p>
<p>What are the 2 types of equilibria?</p>	<ul style="list-style-type: none"> <li>Homogeneous equilibria - reactants and products are in the same physical states</li> <li>Heterogeneous equilibria - reactants and products</li> </ul>

	are in different physical states																									
What method should you always use for $K_c$ questions?	<ul style="list-style-type: none"> <li>• Mole <u>Ratio</u></li> <li>• Initial moles</li> <li>• Change in moles</li> <li>• Equilibrium moles</li> </ul> <p>Unless you can readily identify the limiting reactant, assume that the reactant listed first is the one that is limited. If true, all of that reactant will be completely used.</p> <p>Therefore, the reaction will consume all of that reactant. This is signified by subtracting all of that reactant.</p> <table border="1"> <thead> <tr> <th></th> <th>2 K<sub>3</sub>PO<sub>4</sub></th> <th>3 CaCl<sub>2</sub></th> <th>6 KCl</th> <th>Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>R</td> <td>2 mol</td> <td>3 mol</td> <td>6 mol</td> <td>1 mol</td> </tr> <tr> <td>I</td> <td>2.4 mol</td> <td>2.7 mol</td> <td>0 mol</td> <td>0 mol</td> </tr> <tr> <td>C</td> <td>-2.4 mol</td> <td></td> <td></td> <td></td> </tr> <tr> <td>E</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>The final step in methanol synthesis is represented by the following equation:</p> $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ <p>Initially, a sealed container held 20.1 mol of carbon monoxide and 24.2 mol of hydrogen. An equilibrium was reached at 600 K, with 2.16 mol of methanol present in the mixture. Determine the number of moles of carbon monoxide and hydrogen present in the equilibrium mixture.</p> $\begin{array}{ccccccc} & 1 & : & 2 & & 3 & 1 \\ & CO & + & 2H_2 & \rightleftharpoons & CH_3OH \\ I & 20.1 & & 24.2 & & & \\ C & -2.16 & & -4.32 & & & \\ E & 17.94 & & 19.86 & & & \end{array}$ <p style="border: 1px solid red; padding: 2px;">2.16 × 2</p> <p><i>Tip: use acronym of RICE</i></p>		2 K <sub>3</sub> PO <sub>4</sub>	3 CaCl <sub>2</sub>	6 KCl	Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	R	2 mol	3 mol	6 mol	1 mol	I	2.4 mol	2.7 mol	0 mol	0 mol	C	-2.4 mol				E				
	2 K <sub>3</sub> PO <sub>4</sub>	3 CaCl <sub>2</sub>	6 KCl	Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>																						
R	2 mol	3 mol	6 mol	1 mol																						
I	2.4 mol	2.7 mol	0 mol	0 mol																						
C	-2.4 mol																									
E																										

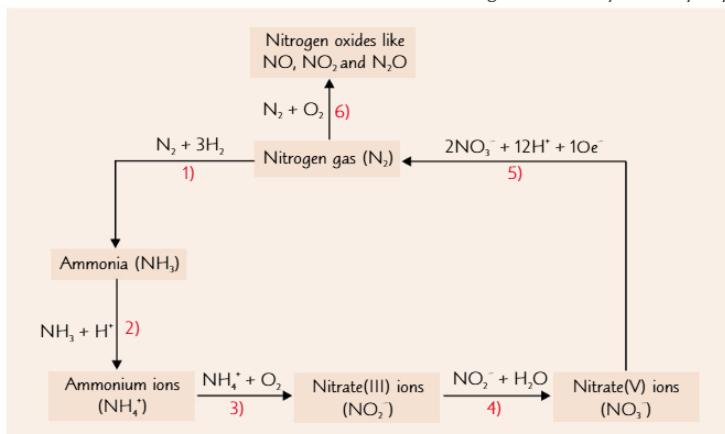
## Cl.i-j - Inorganic chemistry and the periodic table | Cl1 |

What is the dot cross diagram for ammonium?	<p>[1]</p>	<p>31 a [ ] 1 1.1 IGNORE brackets</p>
What is the systematic names for N <sub>2</sub> O, NO and NO <sub>2</sub> ?	<ul style="list-style-type: none"> <li>• Nitrogen(I) oxide</li> <li>• Nitrogen(II) oxide</li> <li>• Nitrogen(IV) oxide</li> </ul>	
What is the appearance of nitrogen(II) oxide   nitric oxide   NO  ?	Colourless gas	<p>Turns to brown NO<sub>2</sub> in air/atmosphere VERY IMPORTANT TO REMEMBER COMES UP ALOT ON EXAM PAPERS</p> <p>31 b iv (colourless gas turns to a brown gas ✓) 1 1.2</p>
What is the appearance of nitrogen(IV) oxide  nitrogen dioxide   NO <sub>2</sub>  ?	Brown gas	
What is the appearance of nitrogen (I) oxide   dinitrogen oxide   dinitrogen monoxide   N <sub>2</sub> O  ?	Colourless gas	

What is the oxidation state of nitrogen in NH <sub>3</sub> , NH <sub>4</sub> <sup>+</sup> & NH <sub>4</sub> Cl	-3						
What is the test for ammonia ions?  (ii) Describe a test that students could do to confirm the presence of ammonium ions in a fertiliser.  ..... ..... ..... [1]	1. Add sodium hydroxide solution and heat gently 2. Then hover red litmus paper over the tube and it should turn blue if NH <sub>3</sub> is present  [You would see dense white misty fumes due to ammonia] <table border="1" style="margin-left: auto; margin-right: auto;"><tr><td>31</td><td>b</td><td>i</td><td>(Warm with) sodium hydroxide AND gas/ammonia/fumes turns indicator paper/red litmus paper blue✓</td><td>1</td><td>1.2</td></tr></table>	31	b	i	(Warm with) sodium hydroxide AND gas/ammonia/fumes turns indicator paper/red litmus paper blue✓	1	1.2
31	b	i	(Warm with) sodium hydroxide AND gas/ammonia/fumes turns indicator paper/red litmus paper blue✓	1	1.2		
What is the ionic equation for converting ammonium into ammonia?							

### You Can Interconvert Between Different Compounds of Nitrogen

This is what the **nitrogen cycle** is for — it shows how you can convert nitrogen into other compounds. You need to know how to interconvert between different forms of nitrogen. Must be your lucky day...



Here are the relevant equations (or redox half-equations) for the reactions:

- 1)  $N_2 + 3H_2 \rightarrow 2NH_3$
- 2)  $NH_3 + H^+ \rightarrow NH_4^+$
- 3)  $NH_4^+ + O_2 \rightarrow NO_2^- + 4H^+ + 2e^-$
- 4)  $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$
- 5)  $2NO_3^- + 12H^+ + 10e^- \rightarrow N_2 + 6H_2O$
- 6) E.g.  $N_2 + O_2 \rightarrow 2NO$ ,  $N_2 + 2O_2 \rightarrow 2NO_2$ ,  $2N_2 + O_2 \rightarrow 2N_2O$

### CI.k - Sustainability | CI6 |

Define co product and by-product?	<ul style="list-style-type: none"> <li>• Co-product: Is a product in the same <b>reaction</b> as a desired product</li> <li>• By-product: A product produced in a side reaction</li> </ul>
-----------------------------------	--

## ***There are Both Benefits and Risks Involved in Producing a Chemical***

Large-scale production of chemicals like medicines, fertilisers, cleaning products and dyes, as well as new materials like plastics, has revolutionised our lives. Where would we be without aspirin, household bleach and blue denim? In a pretty pickle, I tell you. But chemical production is not without risks...

- 1) Some chemicals, especially gases, are **highly flammable** and carry the risk of **explosion**, e.g. propane, pressurised hydrogen. They must be stored and handled correctly to minimise this risk.
- 2) Some chemicals are **harmful to our health** if we come into contact with them or their vapours. Chlorine, for example, is **toxic** if inhaled and can irritate the eyes and lungs. Workers in the chemical industry are most at risk, but an **accident** or **fire** at a chemical plant, or a **spill** during transportation, could also **expose the public** to hazardous material.
- 3) Some chemicals can also **damage the environment**. Sulfur dioxide is a **by-product** of sulfuric acid production. It is an **acidic gas** and a contributor to **acid rain**.

## ***There are Many Costs Involved in Producing a Chemical***

When chemical engineers are deciding the most **economical** way to produce a chemical, there are many costs that need to be considered.

### **1) Raw Materials**

The plant needs to buy chemicals for the reaction — cheap, widely available ones are best.

### **3) Overheads/Fixed Costs**

No matter how much fuel or raw material a company uses, there are certain costs that need to be met regularly. These include staff wages, rent of equipment or space, taxes, insurance, telephone bills, etc.

Reactions with **high atom economies** and **high percentage yields** tend to be best because they use fewer raw materials and have fewer waste products. This **saves money** for a company.

### **2) Fuel/Energy**

Reactions needing high temperature or pressure will use up a lot of energy. Energy is also used in transporting chemicals to, from and around a plant, mixing them and purifying products.

### **4) Disposal Costs**

Any unwanted by-products will have to be disposed of safely — this is subject to government regulations and can be very expensive.

By-products are unwanted waste products from a chemical process. You also get co-products — these are products which, whilst not as valuable as the main product, can still be useful and sold on for profit.

Condition	Advantages	Disadvantages
Temperature	<ul style="list-style-type: none"> <li>Reactions go <b>faster</b> at higher temperatures, meaning more product will be made in the same amount of time.</li> </ul>	<ul style="list-style-type: none"> <li><b>High temperatures</b> make reactions more <b>expensive</b> to carry out because of the cost of fuel.</li> </ul>
Pressure	<ul style="list-style-type: none"> <li><b>Higher pressures</b> make <b>gaseous</b> reactions go <b>faster</b>.</li> </ul>	<ul style="list-style-type: none"> <li>To create a high pressure, gas must be <b>pumped</b> into the reaction vessel. Running powerful pumps uses a lot of <b>energy</b> and is <b>expensive</b>.</li> <li>High pressures can be very <b>dangerous</b>. This means that reaction vessels must be made out of a <b>strong material</b> like thick steel, and incorporate <b>safety systems</b>. Again, this is very expensive.</li> </ul>
Catalyst	<ul style="list-style-type: none"> <li>The right catalyst can make a reaction <b>go quickly</b> at <b>relatively low temperatures</b> — in some cases, no heat is needed at all. This saves money on fuel.</li> <li>Catalysts are a <b>good investment</b> because they don't get used up.</li> </ul>	<ul style="list-style-type: none"> <li><b>Industrial catalysts</b> can be <b>expensive</b>.</li> <li>If a catalyst is in the <b>same state</b> as the reactants, it will have to be <b>separated</b> from the reaction mixture once the reaction is complete. This adds an <b>extra step</b> to the industrial process.</li> </ul>