# Teacher Resource and Assessment Book
# Exercises Unit 4—answers

## 64 Exercise: Discovering the equilibrium law

**1 & 2**

| Run | $[H_2]$ | $[I_2]$ | [HI] | $[H_2]$ + $[I_2]$ + [HI] | $\frac{[HI]}{[H_2][I_2]}$ | $\frac{[HI]^2}{[H_2][I_2]}$ |
|---|---|---|---|---|---|---|
| 1 | 0.005 617 0 | 0.000 594 0 | 0.012 699 0 | 0.018 910 0 | 3806.087 | 48.333 49 |
| 2 | 0.004 580 0 | 0.000 993 0 | 0.014 858 0 | 0.020 431 0 | 3266.974 | 48.540 69 |
| 3 | 0.003 842 0 | 0.001 524 0 | 0.016 871 0 | 0.022 237 0 | 2881.366 | 48.611 53 |
| 4 | 0.004 667 0 | 0.001 058 0 | 0.015 445 0 | 0.021 170 0 | 3127.983 | 48.311 70 |
| 5 | 0.001 696 0 | 0.001 696 0 | 0.011 807 0 | 0.015 199 0 | 4104.761 | 48.464 91 |
| 6 | 0.001 433 0 | 0.001 433 0 | 0.009 999 0 | 0.012 865 0 | 4869.274 | 48.687 87 |
| 7 | 0.004 213 0 | 0.004 213 0 | 0.029 435 0 | 0.037 861 0 | 1658.369 | 48.814 09 |

| | | | |
|---|---|---|---|
| **Average** | 0.021 | 3387.830 | 48.537 76 |

**3** The most constant expression is $\frac{[HI]^2}{[H_2][I_2]} = 48.537\,76$

**4**

| Run | $[NO_2]$ | $[N_2O_4]$ | $\frac{[NO_2]^2}{[N_2O_4]}$ |
|---|---|---|---|
| 1 | 0.0010 | 0.0016 | 0.000 625 0 |
| 2 | 0.0031 | 0.0155 | 0.000 620 0 |
| 3 | 0.0060 | 0.0570 | 0.000 631 6 |
| 4 | 0.0110 | 0.1950 | 0.000 620 5 |

| | |
|---|---|
| **Average** | 0.000 624 3 |

$$\frac{[NO_2]^2}{[N_2O_4]} = 0.000\,624\,3 \text{ mol L}^{-1}$$

**5** $K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$



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## 71 Exercise: Equilibrium: interpretation of graphs

**1** Three changes were made to the conditions.

**2** The system was not at equilibrium at: 0.0–3.0, 5.0–7.5, 9.0–10.5, 13.0–15.0 seconds.

**3** $K = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

**4** **a** After 4 seconds:

$[NH_3] = 0.68\ mol\ L^{-1}$, $[N_2] = 2.15\ mol\ L^{-1}$, $[H_2] = 1.55\ mol\ L^{-1}$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{0.67^2}{2.15 \times 1.55^3} = 0.056\ mol^{-2}\ L^2$$

**b** After 8 seconds:

$[NH_3] = 2.28\ mol\ L^{-1}$, $[N_2] = 1.38\ mol\ L^{-1}$, $[H_2] = 4.16\ mol\ L^{-1}$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{2.28^2}{1.38 \times 4.15^3} = 0.0530\ mol^{-2}\ L^2$$

**c** After 12 seconds:

$[NH_3] = 2.68\ mol\ L^{-1}$, $[N_2] = 1.20\ mol\ L^{-1}$, $[H_2] = 2.55\ mol\ L^{-1}$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{2.68^2}{1.20 \times 2.55^3} = 0.361\ mol^{-2}\ L^2$$

**d** After 16 seconds:

$[NH_3] = 6.41\ mol\ L^{-1}$, $[N_2] = 1.82\ mol\ L^{-1}$, $[H_2] = 5.44\ mol\ L^{-1}$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{6.41^2}{1.82 \times 5.44^3} = 0.140\ mol^{-2}\ L^2$$

**6** **a** Additional hydrogen added to the system

**b** Temperature change

**c** Temperature change

**7** Similar graph but on a shorter time scale



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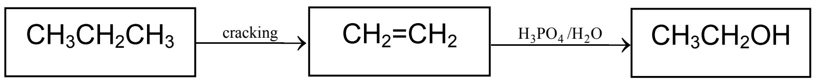
# 76 Exercise: Factors affecting the industrial synthesis of a chemical

**1**




**2** $CH_3CH_2CH_3(g) \rightarrow CH_2{=}CH_2(g) + CH_4(g)$ $\Delta H = 81$ kJ mol$^{-1}$

$CH_2{=}CH_2(g) + H_2O(g) \xrightarrow{H_3PO_4} CH_3CH_2OH(g)$ $\Delta H = -45$ kJ mol$^{-1}$

**3** Fractional distillation

**4** Phosphoric acid acts as a catalyst.

A high level of conversion is obtained by recycling the unreacted gases back over the catalyst.

**5** Conditions are chosen to produce an economic yield. This involves balancing rate and equilibrium considerations

*Temperature*

Effect on equilibrium: The equilibrium needs to be shifted as far as possible to the right in order to produce the maximum possible amount of ethanol in the equilibrium mixture. Le Chatelier's principle indicates that a low temperature is favoured.

Effect on rate: Lowering the temperature will increase the yield but not the rate so there is a need to compromise.

*Pressure*

Effect on equilibrium: Le Chatelier's principle indicates that if you increase the pressure, the system will respond by favouring the reaction that produces fewer molecules. So a high pressure is needed. Unfortunately high pressures are expensive to maintain and the ethene polymerises to make poly(ethene).

**6** **a** Increase the yield of ethanol.

**b** Decrease the yield of ethanol.

**7** Waste management: recycling unreacted gases and heat

Fire prevention procedures will need to be considered as both the reactants and products are flammable.

**8**
- Less reliance on hydrocarbon fuel.
- Lower production of greenhouse gases since the $CO_2$ released during combustion is balanced by the $CO_2$ consumed during photosynthesis. This does not take into account the $CO_2$ generated in the tilling of the land, production of fertilisers, the conversion of the crop to ethanol and the transport of the crop and fuel.
- The use of agricultural land to produce biofuels rather than food crops or pasture will lead to less land available for food production, leading to higher food prices.



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## 78 Exercise: Flowcharts of the manufacture of an industrial chemical

The VCE Chemistry course requires students to complete a detailed study of one chemical selected from ammonia, nitric acid, sulfuric acid or ethene.

Completion of the flowcharts will provide students with a comprehensive summary of the industrial production of the selected chemical including rate and equilibrium factors, waste management, health and safety issues and properties and uses.

Detailed information about these is provided in *Heinemann Chemistry 2*, Chapters 19–22.

## 79 Exercise: No worries mate—she'll be right

The following chemical hazard data has been obtained from the Chemical Hazard Information System website at http://hsis.ascc.gov.au/.

Hazards are grouped into three categories: chemical, health and environmental hazards. Specific risk statements are obtained from the above website. The risk statements are also available on the Teacher Resource and Assessment Disc (TRAD) accompanying the Teacher and Resource Assessment Book.

**1** Ammonium dichromate

Chemical hazards

Explosive; R1 Explosive when dry

Oxidant; R8 Contact with combustible material may cause fire.

Health hazards

Carcinogenic; R49 May cause cancer by inhalation

Mutagenic; R46 May cause heritable genetic damage.

Very toxic; R26 Very toxic by inhalation.

Toxic; R25 Toxic if swallowed.

Harmful; R21 Harmful in contact with skin

Irritant; R37/38-41 Irritating to respiratory system and skin. Risk of serious eye damage. R43May cause sensitisation by skin contact

Environmental hazards

Dangerous for the environment; R50-53 Very toxic to aquatic organisms



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Chromium(VI) oxide

*Chemical hazards*

Oxidant; R8 Contact with combustible material may cause fire.

*Health hazards*

Carcinogenic; R49 May cause cancer by inhalation

Toxic; R25 Toxic if swallowed.

Corrosive; R35 Causes severe burns.R43 May cause sensitisation by skin contact.

*Environmental hazards*

Dangerous for the environment; R50-53 Very toxic to aquatic organisms

Asbestos

Carcinogenic; R45 May cause cancer

Toxic; R48 Danger of serious damage to health by prolonged exposure. R23 Toxic by inhalation

**2** A safer volcano experiment could be conducted using a papier-mâché volcano. Place some sodium bicarbonate powder in the cone and add a small amount of vinegar. Adding a red or yellow food dye to the powder provides some more realistic effects.

**3** No experiment should be considered as risk free. A risk analysis undertaken before an experiment using the appropriate Material Safety Data Sheets (MSDS) should identify potential risks and ways of safely dealing with the risks.

The preferred methods of risk control ranked in the order that they should be considered and adopted are:

- elimination—not using a particularly dangerous chemical
- substitution—replacing the chemical or process with a less hazardous one;
- administration—redesign the experiment to limit the risk of exposure
- personal protective equipment—using properly fitted equipment where other control measures are not appropriate.

**4** Retailers such as hardware stores or supermarkets do not have to supply MSDS sheets when ‘chemicals’ are purchased. Part of a chemistry education program should be to make students aware of the potential hazards that chemicals pose and the need to store, handle and dispose of chemicals in a safe manner. A student who studied chemistry should know where to obtain the appropriate MSDS and how to interpret the information correctly.



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## 83 Exercise: Improving yields in sulfuric acid production

**1** **a** First pass: 450 – 615 = 165°C

Second pass: 500 – 450 = 150°C

Third pass: 460 – 430 = 3 0°C

Fourth pass: 450 – 430 = 20°C

**b** The reaction is exothermic. Heat energy is released during an exothermic reaction.

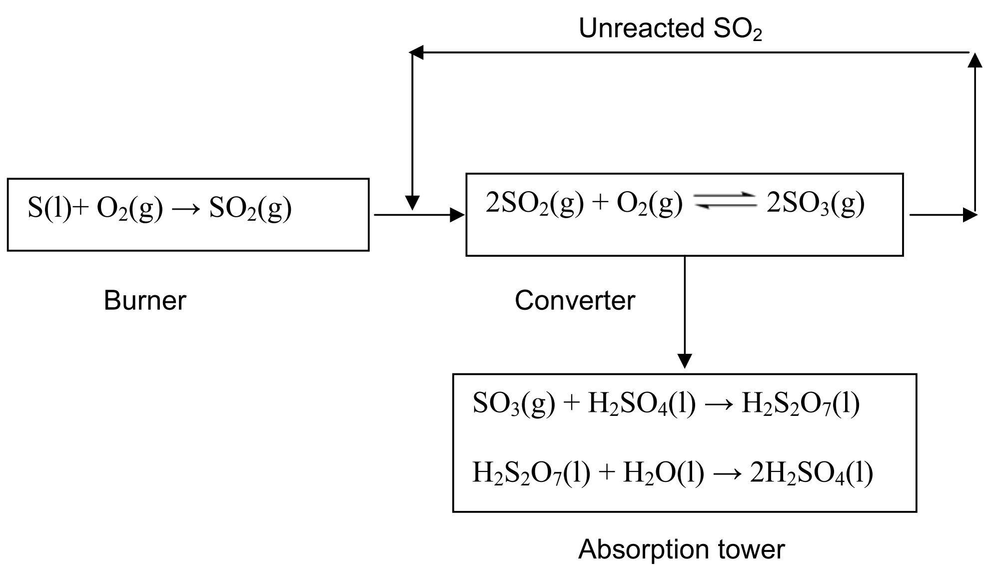
**c** The amount of unreacted $SO_2$ decreases at each pass. Hence, less heat energy is produced at each pass.

**2** For an exothermic reaction, the value of the equilibrium constant is higher at lower temperatures.

**3** The reactions occurring during the contact process are exothermic. The waste heat is recycled in the production of other chemicals or electricity.

**4** Increase the yield of sulfuric acid and hence minimise the cost of production; minimise waste; reduce the amount of $SO_2$ that enters the atmosphere

**5**




## 86 Exercise: Sustainability: the triple bottom-line

Refer to *Heinemann Chemistry 2*, Chapters 23 and 24 for additional information.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## 87 Exercise: Carbon cycle waste management

**1** Carbon dioxide gas, methane gas

**2** **a** $6CO_2(aq) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ $\Delta H = 2803$ kJ mol$^{-1}$

**b** $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(aq) + 6H_2O(l)$ $\Delta H = -2803$ kJ mol$^{-1}$

**c** $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -33$ kJ g$^{-1}$ from dried brown coal

**3** Photosynthesis is endothermic, respiration is exothermic, and combustion of fossil fuels is exothermic.

**4** The operation of a coal-fired power station produces much larger volumes of carbon dioxide than the operation of a nuclear power station. It has been proposed that the carbon dioxide produced by coal-fired power stations may be buried under ground (geosequestration) or that coal be treated to makes its use more efficient and less polluting (clean coal)

**5** The Protocol was negotiated in Kyoto, Japan, in 1997 and is an international agreement designed to limit greenhouse gas emissions. Each developed country such as Australia has been given carbon dioxide emission targets. Carbon trading involves the taxation of carbon dioxide production and tax benefits for carbon dioxide reduction schemes.

Refer to the Australian Academy of Science NOVA website http://www.science.org.au/nova/054/054key.htm.

## 88 Exercise: The future of coal

**1** Geosequestration or carbon sequestration involves storing underground the carbon dioxide produced by industries such as coal-fired power stations. A trial geosequestration project has commenced in south-west Victoria.

**2** Preventing the carbon dioxide produced by industry from entering the atmosphere and thereby contributing to global warming.

**3** Geosequestration is not a proven technique. There is concern about the stability of the underground storage process and about the environmental and safety impact should large amounts of carbon dioxide be quickly released from an underground store.

**4** Alternative energy sources are required to supplement the dwindling petroleum resources.

**5** There are large reserves of brown coal in the Latrobe Valley.

## 89 Exercise: Who's fuelling whom?

The use, cost and environmental impact of using fossil fuels are at times emotive issues. This exercise provides an opportunity to discuss the role of factual information in forming public opinion.


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## Exercise 90: Evaluation of energy sources

Refer to *Heinemann Chemistry 2*, Chapters 11, 23 and 24 and the website www.hi.com.au/chemistry. Further information can be obtained from other websites using an appropriate search engine. The sustainability of energy resources is a topical issue and useful information may be gained from recent press articles.

## 91 Exercise: Energy: linking ideas

There is no correct answer for the use of concept maps. Concept maps provide a visual representation of the ideas students have built up about the interconnectedness between the various concepts or key ideas that make up a particular unit of study. Concept maps are useful tools in gauging students' understanding of a topic.

The words in a concept map may be organised in a random manner or in a hierarchical order. Arrows are drawn between words that are linked. Words or brief sentences that explain the link are written along each arrow. The more links that are made between concepts are an indication of the level of understanding of a student.

## 92 Exercise: Australia's future power generation

### Part A

Alternative uses of brown coal are a developing field. Refer to recent press and Internet articles.

### Part B

Refer to *Heinemann Chemistry 2*, Chapter 24.

 
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## 100 Exercise: Measuring the heat of reaction using second-hand data

**1** To measure the heat of reaction for the reaction between magnesium oxide and hydrochloric acid.

**2** Calorimeter, thermometer, weighing bottles, electronic balance, safety glasses, 100 mL measuring cylinder, DC power supply, voltmeter, ammeter, stopwatch, magnesium oxide, 1.00 M hydrochloric acid.

**3** Electrical equipment must be used carefully. Electric shock or damage to equipment may result from incorrect connection of circuit components. Wear safety glasses and a laboratory coat. 1.00 M HCl may irritate the eyes and respiratory system. MgO can cause irritation to the nasal passages; respiratory tract, and eyes.

**4** The calibration of the calorimeter is outlined 96 Experiment 'Calibration of a calorimeter'. A procedure similar to that outlined in 97 Experiment 'Enthalpy changes in chemical reactions' may be used to measure the heat of reaction between MgO and HCl.

**5** $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$

**6** *Calibration factor*

Energy supplied: $E = VIt = 4.0 \times 2.4 \times 3 \times 60 = 1728$ J

Temperature rise: $\Delta T = 25.3 - 21.6 = 3.7$°C

$$\text{Calibration factor} = \frac{\text{energy supplied}}{\text{temperature change}} = \frac{1728}{3.7} = 467 \text{ J °C}^{-1}$$

The amount of the limiting reagent needs to be determined since the quantities of both reagents are provided.

$$n(\text{HCl}) = cV = 1.00 \times \frac{100.0}{1000} = 0.100 \text{ mol}$$

$$n(\text{MgO}) = \frac{m}{M_r} = \frac{1.00}{40.3} = 0.0250 \text{ mol}$$

Since 1 mole MgO reacts with 2 moles HCl, 0.0250 mole MgO will require 0.0500 mole HCl. Hence HCl is in excess and MgO is the limiting reagent.

*Energy of the reaction*

Temperature change = 29.7 –23.0 = 6.7°C

Energy change = calibration factor × temperature change = 467 × 6.7 = 3128.9 J

0.025mol MgO produces an energy change of 3128.9 J

$$1 \text{ mol MgO will produce } \frac{3128.9}{0.025} = 125\,156 \text{ J}$$

$\Delta H = 125\,156$ J mol$^{-1}$ or 125 kJ mol$^{-1}$ (3 sig. figs)

**7** Possible sources of error:

- A poorly insulated calorimeter will produce a larger value of the calibration factor and $\Delta H$, as the measured temperature change, will be less than the actual temperature change.
- If the volumes of liquid used in the calibration and measuring energy of reaction parts of the experiment were not the same (e.g. if 50 mL of water had been used in the calibration instead of


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100 mL) the calibration factor would be smaller as the temperature rise during calibration would be larger. A smaller calibration factor will lead to smaller values of Δ*H*.

- Errors in measuring mass of MgO, volume of HCl, temperature rise, voltage, current and time.

**8** $2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$ $\Delta H = 125$ kJ $mol^{-1}$



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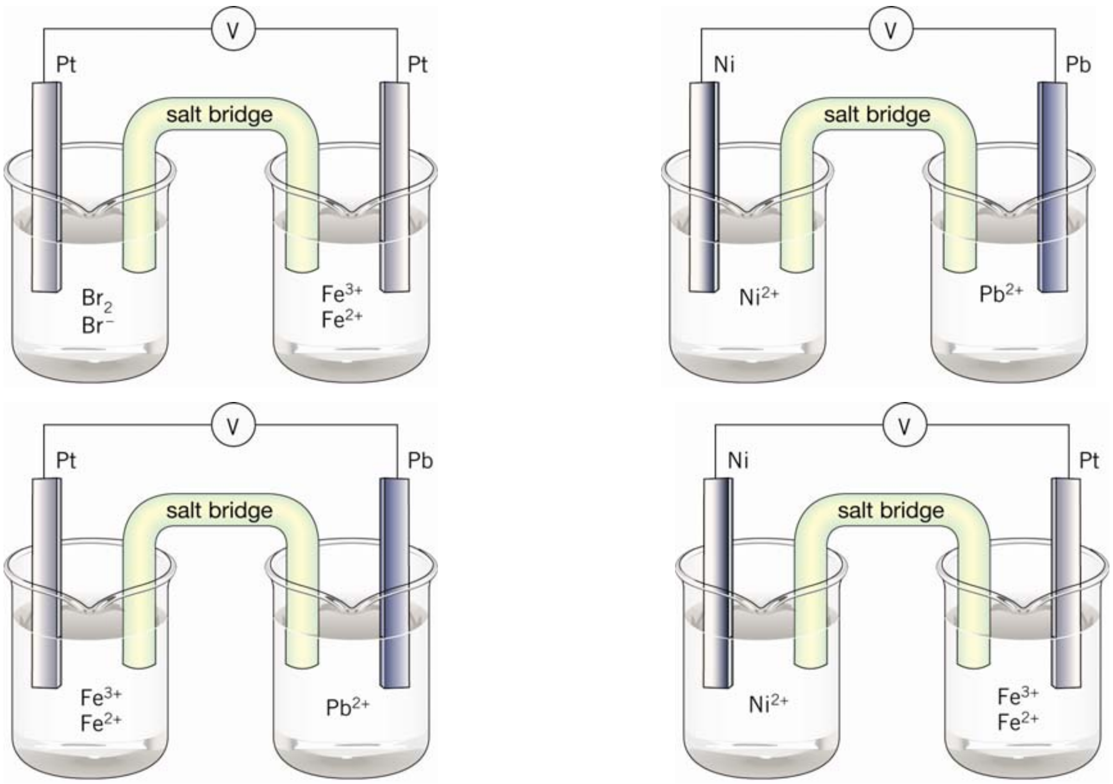
## 103 Exercise: The electrochemical series—an exercise using second-hand data

**1** To use experimental data to construct an electrochemical series for the four half-cells.

**2**




**3** The bromine vapour released from bromine water is harmful if inhaled. Bromine water is harmful if swallowed and can cause eye damage if splashed into the eyes. Prolonged contact with the skin may lead to burns.

Contact with the eyes with potassium bromide can cause irritation.

Iron(II) sulfate is harmful if swallowed.

Iron(III) chloride is corrosive to the skin and is harmful if ingested.

Lead salts are toxic by ingestion or inhalation. They may harm reproductive ability and may also be teratogenic. They may cause cancer and may be systemic poisons. Lead is toxic in the environment.

Lead is a chronic poison. Long-term exposure to airborne lead can be very harmful and result in permanent damage to the nervous system.

Nickel salts may cause cancer. They are toxic and are eye and skin irritants. They are also toxic to aquatic organisms.

**4** A procedure similar to that used in 101 Experiment ‘Half cells and the electrochemical series’ could be used.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**5**

| Half reaction at anode | Half reaction at cathode | Overall reaction |
|---|---|---|
| $Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$ | $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$ | $Br_2(aq) + 2\ Fe^{2+}(aq) \rightarrow 2Br^-(aq) + 2\ Fe^{3+}(aq)$ |
| $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ | $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ | $Pb^{2+}(aq) + Ni(s) \rightarrow Pb(s) + Ni^{2+}(aq)$ |
| $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ | $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$ | $2Fe^{3+}(aq) + Pb(s) \rightarrow 2Fe^{2+}(aq) + Pb^{2+}(aq)$ |
| $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ | $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ | $2Fe^{3+}(aq) + Ni(s) \rightarrow 2Fe^{2+}(aq) + Ni^{2+}(aq)$ |

**6** Electrochemical series.

$Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

**7** The order of half-cell in the electrochemical series is based on standard conditions; 25°C, 1 M concentration, 1 atm pressure. A different order may be obtained if non-standard conditions are used.



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## 106 Exercise: Lithium-based sources of electrical energy.

**1** Lithium metal is a strong reductant. It has a low emf in the electrochemical series. A high voltage can be obtained when lithium metal is combined with a strong oxidant.

**2** Water is a stronger oxidant than $Li^+$ ions and Li metal is a stronger reductant than $OH^-$ ions. There will be a spontaneous reaction between water and metallic lithium

$2Li(s) + H_2O(l) \rightarrow 2Li^+(aq) + 2OH^-(aq) + H_2(g)$

**3** $MnO_2$ is produced at the positive electrode.

**4** At the negative electrode: $Li \rightarrow Li^+ + e^-$

At the positive electrode: $MnO_2 + Li^+ + e^- \rightarrow LiMnO_2$

**5** The electrolyte provides a medium through which ions can move.

**6** A spontaneous reaction will occur if Li and $MnO_2$ are in direct contact. The separator separators the two half reactions, allowing the electron flow to be utilised.

The following websites provide some useful information about lithium batteries**.**
http://www.jaycar.com.au/images_uploaded/battprim.pdf

A good summary of the different types of batteries and how they work.
http://electronics.howstuffworks.com/lithium-ion-battery.htm

An overview of how lithium-ion batteries work

## 112 Exercise: Determining Avogadro's number from electrolysis using second-hand data

**1** $Cu(s) \rightarrow Cu^+(aq) + e^-$

**2** $Cu^+(aq) + OH^-(aq) \rightarrow CuOH(s)$

$2CuOH(s) \rightarrow Cu_2O(s) + H_2O(l)$

**3** $Q = It = 2.27 \times 10 \;\; \times 60 = 1362$ coulomb

**4** No. electrons = $\dfrac{1362}{1.60 \times 10^{-19}} = 8.51 \times 10^{21}$

**5** Mass Cu lost = 186.38 – 185.49 = 0.89 g

$n(Cu) = \dfrac{0.89}{63.9} = 1.40 \times 10^{-2}$ mol

**6** No mol Cu = no mol electrons = no. of electrons

No atoms $1.40 \times 10^{-2}$ mol Cu = no electrons in 1362 C = $8.51 \times 10^{21}$ atoms

Hence no atoms in 1 mol Cu = $\dfrac{8.51 \times 10^{21}}{1.40 \times 10^{-2}} = 6.08 \times 10^{23}$ atoms

**7** Incomplete conversion of $Cu^+(aq)$ to CuOH to $Cu_2O$

Failure to dry electrode before weighing.



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# 114 Exercise: Determination of Faraday's first law of electrolysis using second-hand data

**1** To determine the relationship between the mass of nickel deposited at the cathode and the amount of electric charge passing through the circuit.

**2** A circuit similar to that used in 113 Experiment 'Determination of Faraday's constant and Avogadro's number' may be used.

**3** Refer to safety warnings for 113 Experiment 'Determination of Faraday's constant and Avogadro's number'

**4** Refer to the procedure outlined in 113 Experiment 'Determination of Faraday's constant and Avagadro's number'.

**5** Cathode: $Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$

Anode: $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^{-}$

**6**

| Experiment number | Current (A) | Time (s) | Charge (C) $Q = It$ | Increase in mass (g) |
|---|---|---|---|---|
| 1 | 1.0 | 240 | 240 | 0.069 |
| 2 | 2.0 | 300 | 600 | 0.182 |
| 3 | 1.7 | 180 | 306 | 0.094 |
| 4 | 0.8 | 540 | 432 | 0.131 |



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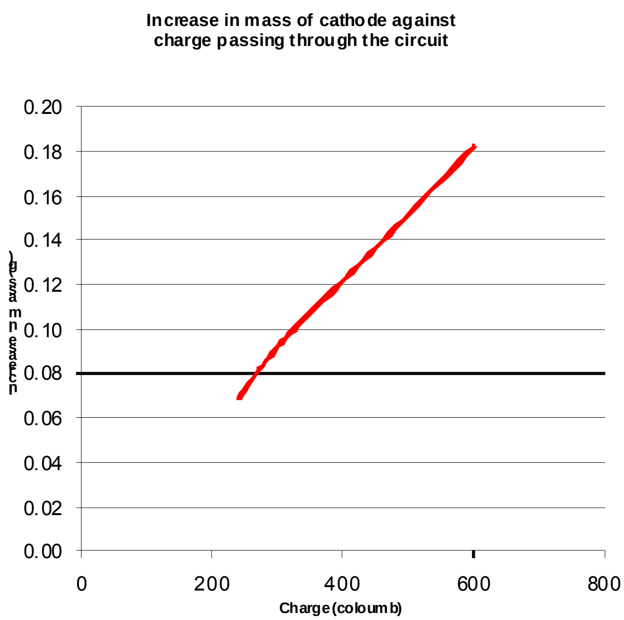


7 Electrodes not dried before weighing. Increase in mass will be recorded as greater than the actual increase.

The amount of liquid retained may vary between samples. This will result in a non-linear graph and a relationship between mass gain and electric charge cannot be determined.

Metal lost from the cathode as the electrode is removed from the cell and dried. This will be recorded as a lower increase in mass than the actual decrease. The amount of matter lost may vary between samples These errors will result in a non-linear graph.



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