VICTORIA UNIVERSITY PRESENTS THE...

2011 VCE LECTURE SERIES

HEALTH, ENGINEERING AND SCIENCE

VCE CHEMISTRY
UNIT 4: CHEMISTRY AT WORK

REVISION NOTES

DATE: THURSDAY 29 SEPTEMBER 2011
Prepared by: Neale Peters

vu.edu.au
CRICOS Provider No. 00124K

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

BACHELOR OF INFORMATION TECHNOLOGY (NETWORK AND SYSTEMS COMPUTING) VTAC code 40811

The Bachelor of Information Technology (Network and Systems Computing) prepares students for a graduate level position within the IT industry. Currently there is a growing market need for graduates skilled in systems administration with networking expertise and this degree equips students with the knowledge and skills required. The program prepares students for IT Industry Certifications (CISCO/Microsoft) and for a career in the fields of networking, databases, and systems administration. The course is offered over three years on a full-time basis (part-time equivalent) at the Footscray Park Campus. With the skills you develop, you could be looking at a range of career options in:
Business Analysis & Consulting
Computing & Network Support
Database Administration
Network & Systems Administration
Project Management
Secondary Teaching
Systems Security Consultancy
Web-based Programming
Prerequisites: Units 3 and 4 – a study score of at least 20 in English (any) and ANY Mathematics.

BACHELOR OF ENGINEERING SCIENCE (SPORTS ENGINEERING) VTAC code 40881

Bachelor of Engineering Science (Sports Engineering) prepares students for a career in the fields of sports, sports science, and exercise and rehabilitation. The primary objective of this program is to produce graduates who are universally recognised as leading practitioners in their field and who, as Sports Engineers, are capable of making a contribution to society and the community.
This program develops students into highly skilled engineering technologists who will be able to provide knowledge-based practical engineering services/solutions to the sports, sports science, and exercise and rehabilitation industries. The course is offered over three years on a full-time basis and will take full advantage of the new $53 million specialist Sports and Exercise Sciences complex at the Footscray Park campus. With the skills you develop, you could be looking at a range of career options such as:
Scientists
Coaches
Elite Athletes
Sporting Goods Manufacturers
Venue Managers
Prerequisites: Units 3 and 4–a study score of at least 24 in English (any) and in one of further mathematics, mathematical methods or specialist mathematics.

BACHELOR OF SCIENCE (Specialisations in Biotechnology, Chemistry or Environmental Management) VTAC code 40691

We produce graduates with a thorough knowledge of contemporary science for careers in industry, government and education. If you want to be a: biotechnologist; chemist; ecologist or environmental scientist; the Bachelor of Science (Specialisation) is the course for you.
The course offers major studies in the abovementioned professions, where students can choose to specialise in one or two science disciplines. This is a three year course with elective choices in the latter two years that allows students the flexibility to add other studies of interest to their specialisation. Specialisations are offered subject to student numbers.
Science at Victoria University is industry focussed, offers an intensive hands-on laboratory experience, has modern laboratories with state-of-the-art equipment, provides opportunities for industry projects and placements and overall better prepares students for careers in the science profession. Those students with scientific research in mind can progress into Honours and postgraduate studies.
Prerequisites: Units 3 and 4 – a study score of at least 20 in English (any) and ANY Mathematics.

SCHOLARSHIPS ENTER AT 70

Available for all Engineering, IT (networking and systems computing), Science Specialisation and Nutrition, Health and Food Sciences courses for students with an ATAR (Enter) of 70 and above who meet the requirements.
See www.vu.edu.au/hes for more information and application form.

ALTERNATIVE ENTRY FOR **ENGINEERING** (VTAC code 41441) **SCIENCE** (VTAC code 41451)

Alternative entry program to engineering and science courses for students who have:

- Successfully completed year 12 with the required prerequisites, but may not have achieved the required study score in all prerequisites;

or

- Have not studied the required mathematics prerequisite.

All admissions are on an individual basis. All applicants offered a place would be required to enroll in one or more subjects from the Foundation Year.
Prerequisites: Units 3 and 4 – English (any) and mathematics (any). ATAR (ENTER) 50+

VCE CHEMISTRY

UNIT 4:
CHEMISTRY AT WORK

REVISION LECTURE

Neale Peters
29 September 2011

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CRICOS Provider No: 00124K

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

UNIT 4 CHEMISTRY EXAM DETAILS

- EXAM FORMAT SAME AS UNIT 3
  - Monday 14 November, 9.00 am
  - 15 min Reading Time
  - 90 min Writing Time
  - ~20 multi-choice questions (~20-25 min)
  - short answer questions
  - equal weighting on Areas of Study 1 and 2
    1. Industrial Chemistry
    2. Supplying & Using Energy
- NEW COURSE IN 2008
  - Industrial Chemistry shifted from Unit 3 into Unit 4
  - BEWARE WHEN USING EXAMS FROM 2007 OR EARLIER FOR REVISION

UNIT 4 CHEMISTRY
AoS 1: INDUSTRIAL CHEMISTRY

Significant changes to Unit 4 in the Study Design in 2008

- Much of the content was previously Unit 3 material

Important when using pre 2008 resources – use UNIT 3 EXAMS

- collision theory and factors that affect the rate of a reaction including activation energy;
- energy profile diagrams and the use of ΔH notation;
- reversible reactions: homogeneous equilibria and the equilibrium law, Le Chatelier's Principle and factors which affect the position of equilibrium;
- pH as a measure of strength of acids and bases; K_w, K_a for weak acids;
- principles of waste management used in the chemical industry;
- the industrial production of the selected chemical
  - factors affecting the production including rate and equilibrium position, catalysts, temperature, pressure
  - waste management including generation, treatment and reduction
  - health and safety
  - uses of the selected chemical

UNIT 4 CHEMISTRY
AoS 2: SUPPLYING & USING ENERGY

- Relatively few changes in new Study Design
- Pre 2008 use Unit 4 Exams but note some shifts in emphasis

- comparison of energy sources: types, uses and sustainability of sources including brown coal, natural gas, nuclear fission and biochemical fuels;
- application of calorimetry to measure energy changes in chemical reactions in solution calorimetry and bomb calorimetry;
- use of the electrochemical series in predicting the products of redox reactions and writing half equations;
- limitations of predictions made using the electrochemical series;
- the construction and operation of simple galvanic primary and secondary cells;
- the construction and operation of fuel cells: advantages and disadvantages of fuel cells compared to conventional energy sources;
- the construction and operation of simple electrolytic cells: comparison of electrolytic cells;
- application of Faraday's laws in electrochemistry.

UNIT 4 CHEMISTRY
RELEVANT UNIT 3 CONTENT

- Mole & stoichiometry
  - Equilibrium Law
  - ΔH calculations
  - Faraday's Laws
- Acid-base reactions and pH calculations
  - relates especially to K_w and K_a
- Redox reactions, oxidation numbers and half-equations
  - Electrochemical Series
  - Cells
- Biofuels
  - Comparison of energy sources

UNIT 4 CHEMISTRY
DATA BOOKLET

- RELEVANT TO UNIT 4
  1. Periodic table
  2. Electrochemical series
     ☒ VERY IMPORTANT
  3. Physical Constants, especially
     ☒ charge on electron
     ☒ Faraday constant
     ☒ K_w at 298K
     ☒ Specific heat capacity of water
  4. SI prefixes
  11. Acid-base indicators (K_a)
  12. K_a values for some weak acids
  13. Molar enthalpies of combustion
- NOT RELEVANT TO UNIT 4
  5. ^{1}H NMR data
  6. ^{13}H NMR data
  7. IR data
  8. Amino acids
  9. Fatty acids
  10. Biomolecules

FAMILIARISE YOURSELF THOROUGHLY WITH THE RELEVANT SECTIONS

UNIT 4 CHEMISTRY
Important Formulae

MOLE/STOICHIOMETRY

$n=m/M$
$n=N/N_A$
$n=cV$
$n=V/V_m$
$pV=nRT$
$n(e^-)=Q/F$
$Q=It$, so $n(e^-)=It/F$

OTHER

$pH= -\log[H^+]$
$[H^+]= 10^{-pH}$
$E=VIt$ (hence $E=VQ$)
$\Delta E= m\ c\ \Delta T$
$\Delta E=$ calibration factor x ΔT
$K_w= [H^+][OH^-]$

$$K_a= \frac{[H^+][A^-]}{[HA]}$$

d (density) = m/V

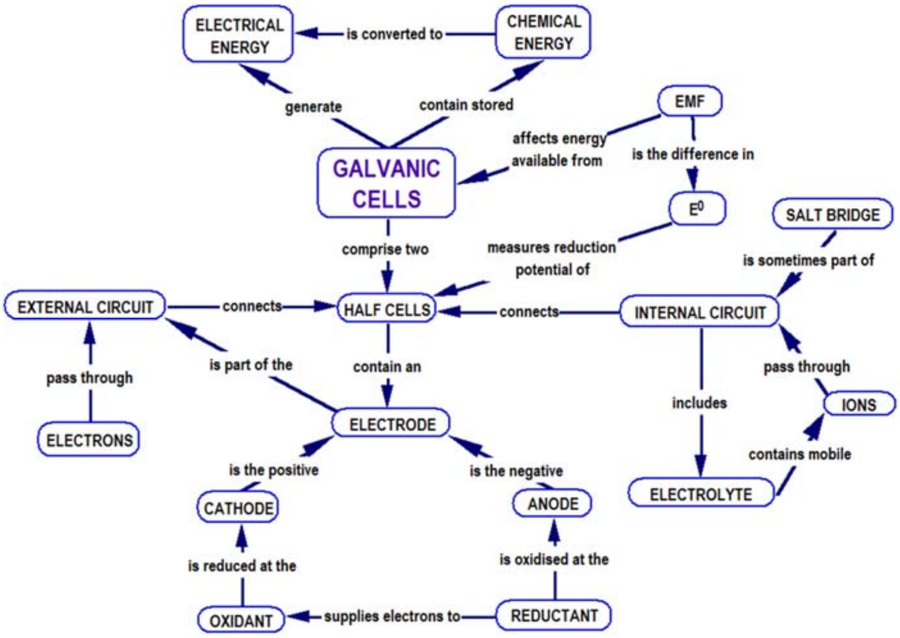
UNIT 4 CHEMISTRY
REVISING EFFECTIVELY - NOTES

- Prepare detailed notes for descriptive topics that require memorisation, principally
  1. Energy Sources - Uses and sustainability
     - brown coal, natural gas, nuclear fission, biochemical fuels, etc
  2. One Industrial Process
     - Ammonia, ethene, sulfuric acid, or nitric acid
- For topics with a more conceptual focus, distil the key concepts
  - Conceptual grasp is more important than memorising details of cells studied
  - Perhaps develop a GLOSSARY of terms and definitions,
  - eg for GALVANIC CELLS:

    CELL, HALF CELL, INTERNAL CIRCUIT, EXTERNAL CIRCUIT, ANODE, CATHODE, OXIDANT, REDUCTANT, ELECTROLYTE, etc

UNIT 4 CHEMISTRY
REVISING EFFECTIVELY - NOTES

- … and/or develop concept maps to summarise the important ideas



UNIT 4 CHEMISTRY
REVISING FOR UNDERSTANDING

- Don't just memorise formulae and plug in numbers
  - rehearse the *meaning* of each quantity
  - know the appropriate units

- The meaning of a quantity can make the formula unnecessary; eg:
  - 'molar' quantities
    - molar mass, M=m/n : mass of one mole of a substance
    - molar volume, V_m=V/n : volume of one mole of a substance (gas)
    - molar charge (Faraday Constant), F=Q/n : charge of one mole of electrons

  - specific heat capacity: $c(H_2O) = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$
    - it takes 4.18 Joules of heat to make 1g of water hotter by 1 °C

    ⇨ hence , 4.18 J for every gram of water for every 1 °C of temp.

    ⇨ $\Delta E = c \times m \times \Delta T = m c \Delta T$

UNIT 4 CHEMISTRY
REVISING FOR UNDERSTANDING

How many Faradays of charge are required to form 1.50 mol of Aluminium in the Hall Cell: $Al^{3+}(l) + 3e^- \rightarrow Al(l)$?

- The robotic student thinks:

  "OK, I've got the moles of aluminium, so I could use n=m/M. No I don't need the mass.
  What do I need? Charge; OK that's Q isn't it – I need that formula with Q in it
  There's Q=It, but I don't have the current or time
  … so it must be the other one: Q=nF
  … or is it Q=n/F? Q=nF? Q=n/F? (dammit!!)
  No, I'm sure it's Q=nF
  OK, there's 1.50 moles, so: n=1.50"

- and so writes:

  Q=nF=1.50 x 96500 = 144750 ✗

UNIT 4 CHEMISTRY
REVISING FOR UNDERSTANDING

How many Faradays of charge are required to form 1.50 mol of Aluminium in the Hall Cell: $Al^{3+}(l) + 3e^- \rightarrow Al(l)$?

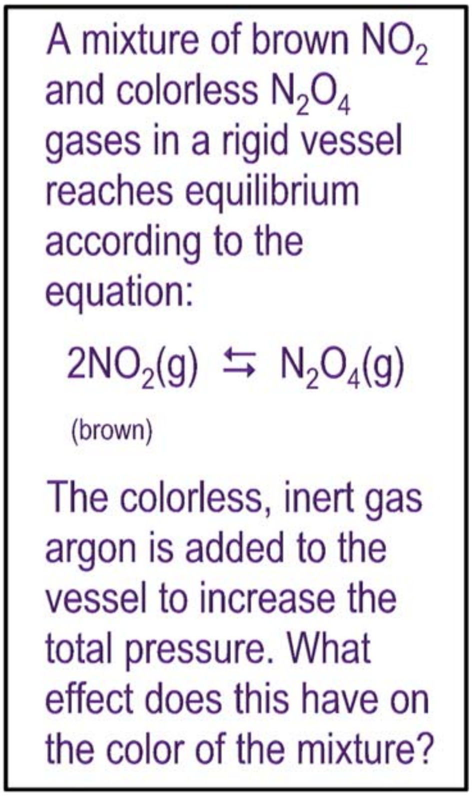
- The logical student says:

  "Let's see: usually charge is in Coulombs but I need the number of Faradays here.
  one Faraday of charge is the charge on one mole of electrons
  … so what I really need here is the number of moles of electrons
  oh – that's easy: the half-equation tells me I need 3 moles of electrons per mole of Al"

- and so writes:

  $n(e^-) = 3 \times n(Al) = 4.50$ mol
  ⇨4.50 Faradays of charge needed ✓

UNIT 4 CHEMISTRY
A TRICKY QUESTION



A mixture of brown NO_2 and colorless N_2O_4 gases in a rigid vessel reaches equilibrium according to the equation:

$$2NO_2(g) \leftrightarrows N_2O_4(g)$$

(brown)

The colorless, inert gas argon is added to the vessel to increase the total pressure. What effect does this have on the color of the mixture?

•If you have memorised all the variations on Le Chatelier's principle, you might think as follows:

> "OK, the pressure increases
> … so this is one of those problems where what matters is the number of particles on either side of the equation.
> Here there are fewer particles on the right
> my notes said: "a pressure increase causes a shift to the side with fewer particles"
> … so this one will shift to the right"

- and so write:

  "pressure increases, so by LCP there is an equilibrium shift to the right, the side with fewer particles, to partially oppose the pressure increase
  ⇨mixture becomes less brown" ✗

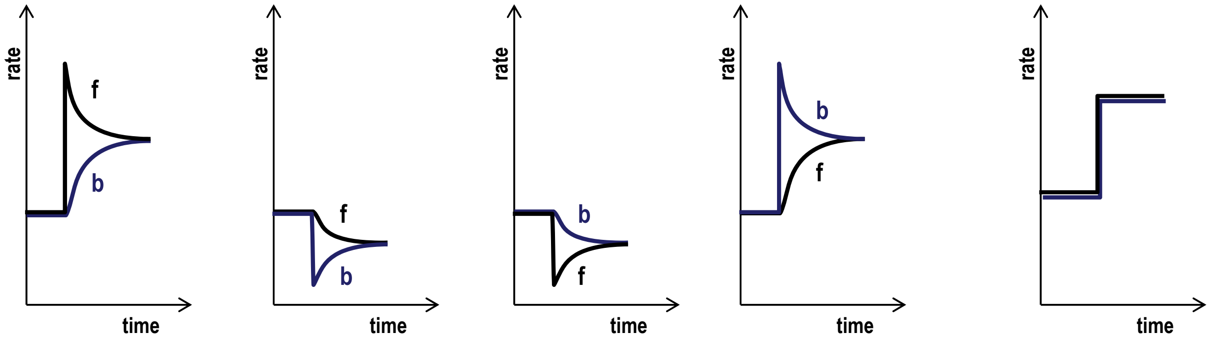
UNIT 4 CHEMISTRY
A TRICKY QUESTION

- Let's analyse the fundamental principles here:
- What is chemical equilibrium?
  - a dynamic, steady state resulting from the *equal rates* of opposing changes, ie forward and reverse reactions
- What is an equilibrium 'shift'?
  - a change in the composition of a mixture resulting from the *unequal rates* of forward and reverse reactions
- When will an equilibrium shift occur?
  - when any change causes the rates of forward and reverse reactions to become unequal
    - reaction rates are governed by COLLISION theory

UNIT 4 CHEMISTRY
EQUILIBRIUM SHIFTS – A RATE ISSUE

$$\text{REACTANTS} \underset{\text{rate}_b}{\overset{\text{rate}_f}{\rightleftharpoons}} \text{PRODUCTS}$$

add reactant	remove product	remove reactant	add product	add catalyst
⇨ increase rate_f	⇨ decrease rate_b	⇨ decrease rate_f	⇨ increase rate_b	⇨ increase rate_f & rate_b
$\rightleftharpoons$	$\rightleftharpoons$	$\rightleftharpoons$	$\rightleftharpoons$	$\rightleftharpoons$



$\text{rate}_f > \text{rate}_b$	$\text{rate}_f > \text{rate}_b$	$\text{rate}_f < \text{rate}_b$	$\text{rate}_f < \text{rate}_b$	$\text{rate}_f = \text{rate}_b$
⇨ shift right	⇨ shift right	⇨ shift left	⇨ shift left	⇨ no shift

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UNIT 4 CHEMISTRY
A TRICKY QUESTION

A mixture of brown NO_2 and colorless N_2O_4 gases in a rigid vessel reaches equilibrium according to the equation:

$$2NO_2(g) \leftrightarrows N_2O_4(g)$$

(brown)

The colorless, inert gas argon is added to the vessel to increase the total pressure. What effect does this have on the color of the mixture?

How does the Key Idea of rates apply?

- the addition of argon does not change the concentration of reactants or products

⇨ the rate of collisions between reactant particles (and between product particles) is not changed

⇨ so that either

  - the rates of forward and reverse reactions are unaffected by the argon, or
  - the argon has a catalytic effect that increases the rates of forward and reverse reactions equally

⇨ either way the rates remain equal

- and hence:

The addition of argon affects the forward and reverse reactions equally (or not at all) so that no shift occurs

⇨no change in the colour of the mixture ✓

UNIT 4 CHEMISTRY SUMMARISING

TOP LEFT-BOTTOM RIGHT

- What's the 'difficulty' here?
  - Le Chatelier's principle is a useful way to predict an equilibrium shift.
  - Le Chatelier's principle is not the '*reason*' that an equilibrium shift occurs.
  - The KEY IDEA in analysing equilibrium changes is the *relative rates* of forward and reverse reactions

LCP

OIL RIG

BACKWARD-Z

- How to ready for tricky problems?
  - Don't become over-reliant on mnemonics, formulae, mathematical tricks without understanding their basis
  - In your revision focus on the KEY IDEAS and do what you can to deepen your understanding

n=m/M

UNIT 4 CHEMISTRY GENERAL REVISION

1. Summarise the KEY IDEAS and the necessary descriptive, factual detail from each topic in your REVISION NOTES
2. Work a range of problems on each topic from
   - textbook
   - tests and SACs
   - "CheckPoints" – (Roger Slade and Maureen Slade, Cambridge Uni Press)
   - commercially available exams and topic tests from, eg
     - STAV, Insight, IARTV, NEAP Lisa Chem
3. Constantly revise and add to your REVISION NOTES as you progress – review and read them regularly
4. Make your teacher work!!
   - ask her/him to check your notes
   - clarify any marking/solutions ambiguities on practice exams
5. Complete as many full papers as you can manage the time for
   - under examination conditions
     - reading time, no interruptions etc

UNIT 4 CHEMISTRY
SOME SPECIFIC STRATEGIES

Analyse each mnemonic/trick/formula/quantity you use

Make sure you can explain what each one means or why it works

Example

Molar mass, M

- M is just the mass of one *mole* of any substance: memorising the formula M=m/n should be unnecessary

Example

“Top Left-Bottom Right” or “Backward-Z”

- this can only be applied to an Electrochemical Series sorted from highest to lowest E^0 value
- it’s a special case of the KEY IDEA that the most likely redox reaction is always between the strongest available reductant and the strongest available oxidant

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UNIT 4 CHEMISTRY
SOME SPECIFIC STRATEGIES

USE THE EXAMINERS’ REPORTS

- These are available from the VCAA website for all VCAA exams that have been sat and marked.
  - take careful note of questions that were done poorly and the examiners’ thoughts on why this was the case
  - look carefully at the mark allocation
  - look at ‘popular’ but incorrect multiple-choice answers and try to determine why they were selected (and why they are wrong!)
  - examine your own responses critically in the light of the examiners’ expectations
  - add noteworthy remarks to your topic summaries as reminders

- NB: before 2008 use Unit 3 Exams for Area of Study 1

UNIT 4 CHEMISTRY
SOME SPECIFIC STRATEGIES

PROBLEM SOLVING STRATEGIES

- First, try to visualise the entire solution pathway
  - for stoichiometric calculations you will have a well-rehearsed sequence:
    - 1. find n(X)→ 2. use mole ratio to find n(Y)→ 3. find answer eg m(Y)
  - for some calculation problems the pathway may require more thought
- If stuck, try to identify what the ‘precursor’ to the final answer will be
  - for example, where the problem is to calculate a pH, the precursor is usually $[H^+]$ – reinterpret the question with this as your target
- Trial and error
  - when all else fails calculate *something* from the data given
    - calculating n(X) might be a dead-end; on the other hand it might be worth a mark
    - that calculated value might just suggest what the next step should be and get you started

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UNIT 4 CHEMISTRY
SOME SPECIFIC STRATEGIES

READ BEYOND THE COURSE

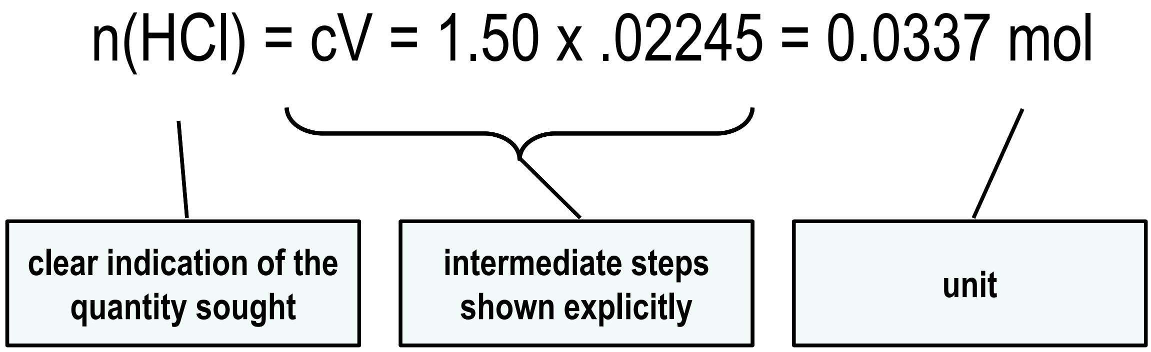
- The more extensive your knowledge of a topic the better equipped you will be to answer VCE-level questions
  - as a minimum, your textbook should have been read cover to cover
    - re-read sections that you feel less confident with
    - re-do questions that have caused you difficulty
  - if you have access to other VCE texts read sections of them as well
    - a slightly different angle from an alternative source might allow a concept you have struggled with to ‘click’
  - there are also a number of good online sources
    - eg www.chemguide.co.uk
    - these sometimes go beyond what is required for VCE but that’s not a bad thing

UNIT 4 CHEMISTRY MAXIMISING MARKS

- How do you ensure you earn the maximum marks?
  - Get the answer right!!
  - Correct chemical language
    - equations balanced
    - states included in every equation
    - correct use of subscripts/superscripts in chemical formulae
  - Significant figures
  - Clear and logical setting out of calculations
    - consequential marks
  - Correct units

UNIT 4 CHEMISTRY MAXIMISING MARKS

- CLEAR & LOGICAL SETTING OUT IS CRITICAL



$$n(HCl) = cV = \underbrace{1.50 \times .02245}_{\text{intermediate steps shown explicitly}} = 0.0337\ \text{mol}$$

clear indication of the quantity sought

intermediate steps shown explicitly

unit

UNIT 4 CHEMISTRY
MAXIMISING MARKS

- SIGNIFICANT FIGURES – ADDING/SUBTRACTING
  - for addition/subtraction the result is rounded to the smallest number of DECIMAL PLACES:
  - eg if adding

$$\begin{array}{lr} & 98.0 \\ + & 5.2131 \\ + & \underline{0.67} \\ & \underline{103.8831} \\ \text{rounds to} & 103.9 \end{array}$$

  - NB: the periodic table in the DATA BOOK gives atomic masses to *one decimal place*.
    - molar masses should be to one decimal place

UNIT 4 CHEMISTRY
MAXIMISING MARKS

SIGNIFICANT FIGURES – MULTIPLYING/DIVIDING

- for multiplication/division the result is rounded to the smallest number of SIGNIFICANT FIGURES:

eg the amount (moles) of HCl in 22.45 mL of a 1.5 M solution is

	1.5	(2 sig figs)
x	0.02245	(4 sig figs)
	0.033675	
rounds to	0.034 mol	(2 sig figs)

BUT the amount (moles) of HCl in 22.45 mL of a 1.5<u>0</u> M solution is

	1.50	(3 sig figs)
x	0.02245	(4 sig figs)
	0.033675	
rounds to	0.0337 mol	(3 sig figs)

AREA OF STUDY 1

INDUSTRIAL CHEMISTRY

UNIT 4 CHEMISTRY– AOS1 STUDY DESIGN – KEY KNOWLEDGE

- collision theory and factors that affect the rate of a reaction including activation energy;
- energy profile diagrams and the use of ΔH notation;
- reversible reactions: homogeneous equilibria and the equilibrium law, Le Chatelier's Principle and factors which affect the position of equilibrium;
- pH as a measure of strength of acids and bases; K_w, K_a for weak acids;
- principles of waste management used in the chemical industry;
- the industrial production of the selected chemical
  - factors affecting the production including rate and equilibrium position, catalysts, temperature, pressure
  - waste management including generation, treatment and reduction
  - health and safety
  - uses of the selected chemical

UNIT 4 CHEMISTRY– AOS1
Rates & Collision Theory

KEY POINTS

- the rate of a reaction is determined by the frequency of fruitful collisions

frequency of fruitful collisions **=** **overall collision frequency** **x** **fraction of collisions with energy higher than activation energy**

increased by
- higher reactant concentrations
- larger solid surface area
- higher temperature

MOST IMPORTANT FACTOR

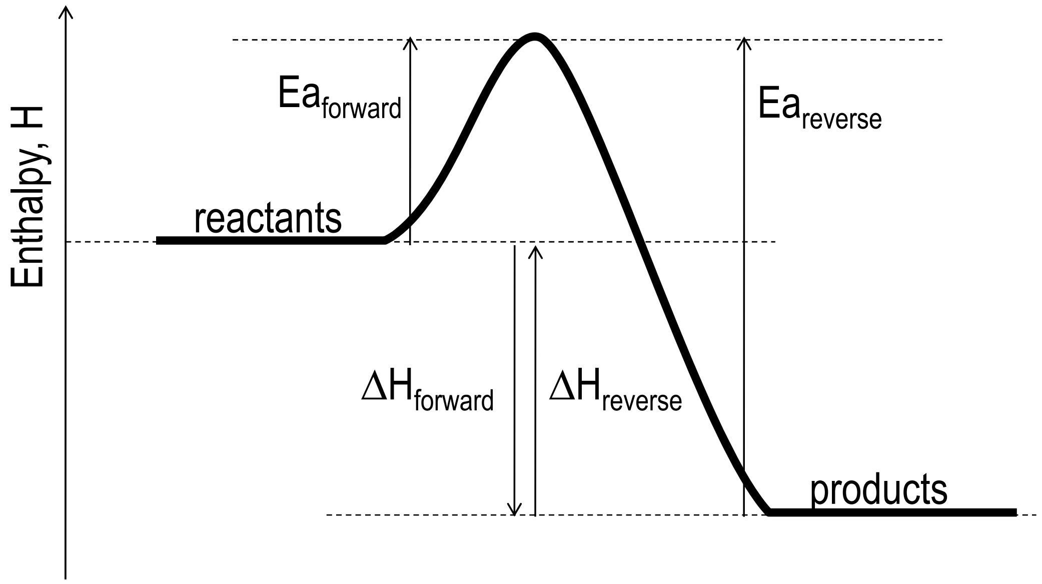
increased by
- higher collision energies
  - higher temperature
- lower activation energy
  - catalyst

- note the ‘double-effect’ of a temperature increase

UNIT 4 CHEMISTRY– AOS1
Energy Profile Diagrams

KEY POINTS

- $\Delta H > 0$ for endothermic reactions; $\Delta H < 0$ for exothermic reactions
- E_a is always positive – minimum energy required to break bonds to initiate reaction



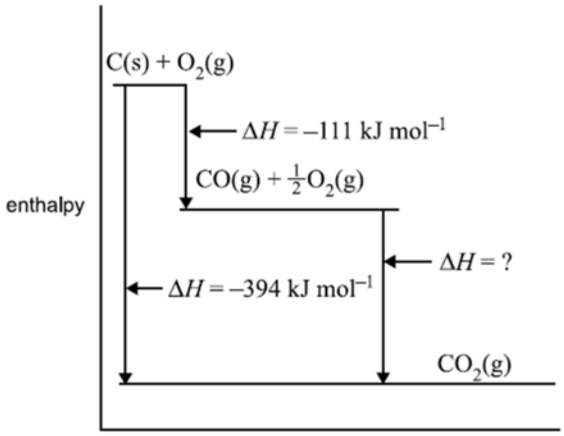
UNIT 4 CHEMISTRY– AOS1
ΔH Notation

KEY IDEAS:

- ΔH values apply to specific *equations*
- the magnitude of ΔH relates to the mole amounts in the equation
- ΔH values are not affected by the conditions of the reaction

$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \quad \Delta H = -111\ kJ\ mol^{-1}$

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -394\ kJ\ mol^{-1}$



From Sample Exam 2007 Q18

Give ΔH for these equations:

$CO(g) + ½O_2(g) \rightarrow CO_2(g)$
$-394-(-111) = -283$ kJ mol^{-1}

$CO_2(g) \rightarrow O_2(g) + C(s)$
$-(-394) = +394$ kJ mol^{-1}

$2C(s) + O_2(g) \rightarrow 2CO(g)$
$2 \times (-111) = -222$ kJ mol^{-1}

$2CO_2(g) \rightarrow O_2(g) + 2CO(g)$
$2 \times -(-283) = +586$ kJ mol^{-1}

UNIT 4 CHEMISTRY– AOS1
ΔH vs Heat of Combustion

KEY IDEA:

- Heat of Combustion is the energy released when a unit quantity (1 mol; 1 g; 1 kg; 1 L, etc) of a fuel is completely combusted

eg for combustion of butane

$2C_4H_{10}(g) + 9O_2 \rightarrow 8CO_2 + 10H_2O(g) \qquad \Delta H = -5748$ kJ mol^{-1}

The HEAT of COMBUSTION of butane is

- heat released by combustion of 1 mol = 5748/2 = 2874 kJ mol^{-1}
- heat released by combustion of 1 g = 2874/58 = 49.6 kJ g^{-1}
- heat released by combustion of 1 L at SLC = 2874/24.5 = 117 kJ L^{-1}
- heat released by combustion of 1 L at 200 kPa and 350 K

  = 2874/(8.31*350/200) = 198 kJ L^{-1}

UNIT 4 CHEMISTRY– AOS1
∆H vs Heat of Combustion

From Sample Exam 2007 Question 4

Octane, C_8H_{18}, is a major constituent of petrol used in cars.

b. i. Write a balanced equation for the complete combustion of octane.

$$C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$

or

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

ii. Give the value and sign of Δ*H for this reaction.*

From the DATA BOOKLET, ΔH_c(octane) = -5464 kJ mol^{-1}

ie combustion of 1 mol of octane releases 5464 kJ of heat

For $C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ $\Delta H = -5464$ kJ mol^{-1}

For $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H = -10928$ kJ mol^{-1}

UNIT 4 CHEMISTRY– AOS1
EQUILIBRIUM LAW

KEY POINTS

- $aA + bB + \ldots \leftrightharpoons xX + yY + \ldots$

$$Q = \frac{[X]^x [Y]^y \ldots}{[A]^a [B]^b \ldots}$$

- for any equilibrium mixture, Q = K
  - K is a constant whose value depends only on the temperature
  - K is independent of
    - the initial composition of the mixture or any subsequent changes
    - pressure, volume, dilution, etc
    - the presence of other chemical species
- three possible cases for any mixture
  1. Q<K – the system is not at equilibrium and a net forward reaction occurs
  2. Q>K – the system is not at equilibrium and a net back reaction occurs
  3. Q=K – the system is already at equilibrium and no net reaction occurs

UNIT 4 CHEMISTRY– AOS1 EQUILIBRIUM LAW

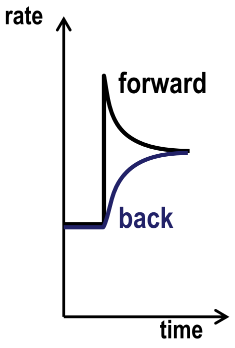
- If a system is at equilibrium
  - rates of forward and back reactions are *equal*
  - concentrations (or pressures of gases) are *constant*
  - Q = K

- If a system is at not at equilibrium
  - rates of forward and back reactions are *unequal*
    - one of the reactions is ‘winning’, so that ...
  - concentrations (or pressures of gases) are *changing*
    - we see changes in the macroscopic properties of the mixture
      - colour
      - pH
      - total gas pressure
      - etc

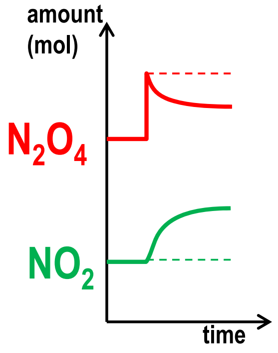
UNIT 4 CHEMISTRY– AOS1 EQUILIBRIUM SHIFTS – GRAPHS

$N_2O_4(g) \leftrightarrows 2NO_2(g)$; K = 5.5×10^{-3} M; $\Delta H>0$ (endothermic)

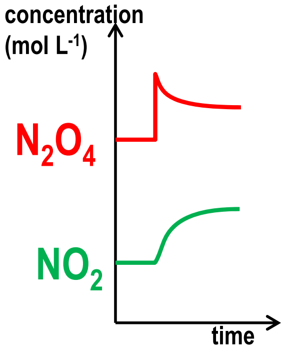
If additional N_2O_4 is added to an equilibrium mixture:



$rate_f > rate_b$
⇨ shift right



$n(NO_2)$ increases
$n(N_2O_4)$ increases
-initial increase
-partial decrease

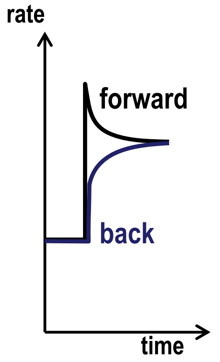


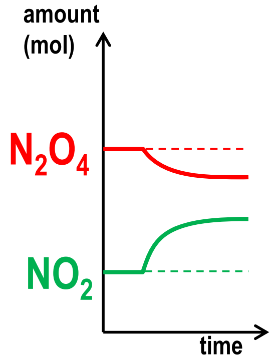
$[N_2O_4]$ increases
$[NO_2]$ increases

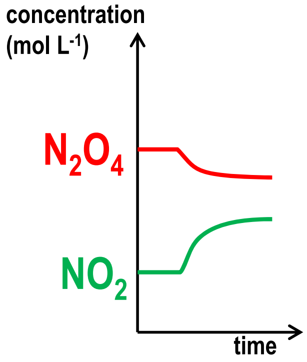
UNIT 4 CHEMISTRY– AOS1 EQUILIBRIUM SHIFTS – GRAPHS

$N_2O_4(g) \leftrightarrows 2NO_2(g)$;   K = 5.5×10^{-3} M;   ΔH>0 (endothermic)

If the temperature is increased, we expect a net forward reaction since the reaction is endothermic:







both rates increase!
-but not equally at first

rate$_f$ > rate$_b$
⇨ shift right

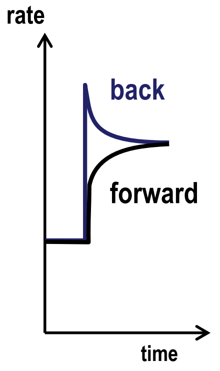
n(N_2O_4) decreases
n(NO_2) increases

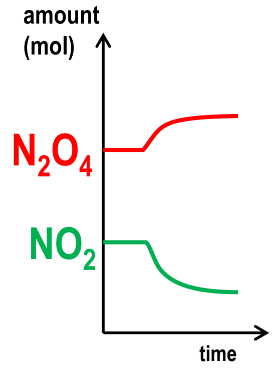
[N_2O_4] decreases
[NO_2] increases

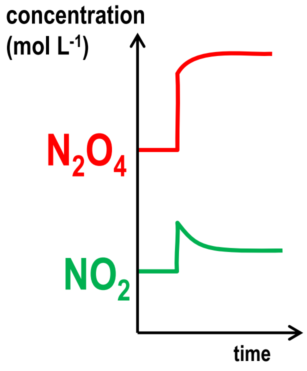
UNIT 4 CHEMISTRY– AOS1 EQUILIBRIUM SHIFTS – GRAPHS

$N_2O_4(g) \leftrightarrows 2NO_2(g)$;   K = 5.5×10^{-3} M;   ΔH>0 (endothermic)

If the volume is reduced (ie gases compressed):







both rates increase!
-but not equally at first

rate$_f$ < rate$_b$
⇨ shift left

n(N_2O_4) increases
n(NO_2) decreases

[N_2O_4] increases
[NO_2] increases
-initial increase
-partial decrease

UNIT 4 CHEMISTRY– AOS1
Le CHATELIER'S PRINCIPLE

- Used to predict equilibrium shifts but not to account for them
  - shifts tend to partially oppose any imposed change, eg

IMPOSED CHANGE		SHIFT OBSERVED
increase in concentration of a reactant	⇨	shift right to reduce concentrations of reactants
decrease in concentration of a product	⇨	shift right to increase concentrations of products
increase in temperature	⇨	shift in the endothermic direction to reduce temperature
dilution of a solution	⇨	shift to the side with more dissolved particles to increase overall concentration
compression of a gas mixture	⇨	shift to the side with fewer particles to reduce the overall pressure
addition of catalyst	⇨	no shift

UNIT 4 CHEMISTRY– AOS1
pH & K_w

KEY IDEAS:

- pH is merely a function of $[H^+]$: $pH = -\log[H^+]$
  - hence $[H^+] = 10^{-pH}$
- Acid-base character depends on relative concentrations of $[H^+]$ & $[OH^-]$
  - If $[H^+]>[OH^-]$ the solution is acidic
  - If $[H^+]<[OH^-]$ the solution is basic
  - If $[H^+]=[OH^-]$ the solution is neutral

- pH measures only $[H^+]$ so pH alone is no indication of acid-base character
  - for neutral solutions pH=7 *only at 25 °C*

UNIT 4 CHEMISTRY– AOS1
pH & K_w

- pH problems cause more difficulty than they should. A “pH problem” is actually a “$[H^+]$ problem”

Which of the following will have a pH of 2?

A. 100 mL of HCl with a **pH=3** added to 10 mL of HCl with a **pH=1**
B. 100 mL of HCl with a **pH=3** added to 100 mL of HCl with a **pH=1**
C. 100 mL of NaOH with a **pH=13** added to 100 mL of HCl with a **pH=1**
D. 100 mL of HCl with a **pH=1** added to 100 mL of **water**

try thinking:

Which of the following will have a $[H^+] = 0.01$ M?

A. 100 mL of HCl with **$[H^+]$=0.001M** added to 10 mL of HCl with **$[H^+]$=0.1M**
B. 100 mL of HCl **$[H^+]$=0.001M** added to 100 mL of HCl with **$[H^+]$=0.1M**
C. 100 mL of NaOH with **$[OH^-]$=0.1M** added to 100 mL of HCl with **$[H^+]$=0.1M**
D. 100 mL of HCl with **$[H^+]$=0.1M** added to 100 mL of **water**

	$n(H^+)_1$ (mol)	$n(H^+)_2$ (mol)	$n(H^+)_{total}$	V_{total}	[H+]
A	0.001x0.1=0.0001	0.1x0.01=0.001	0.0011	0.110 L	0.010 M
B	0.001x0.1=0.0001	0.1x0.1=0.01	0.0101	0.200 L	0.051 M
C	equal amounts of H^+ and OH^- being mixed ⇨neutral				
D	0.1x0.1=0.01	0.0	0.01	0.200 L	0.050 M

UNIT 4 CHEMISTRY– AOS1
pH & K_w

- $K_w = [H^+][OH^-]$ is the equilibrium constant for the *endothermic reaction*:

$$H_2O(l) \leftrightarrows H^+(aq) + OH^-(aq)$$

  - as temperature increases
    - K_w increases
    - the ionisation reaction shifts to the right, *increasing $[H^+]$ and $[OH^-]$*

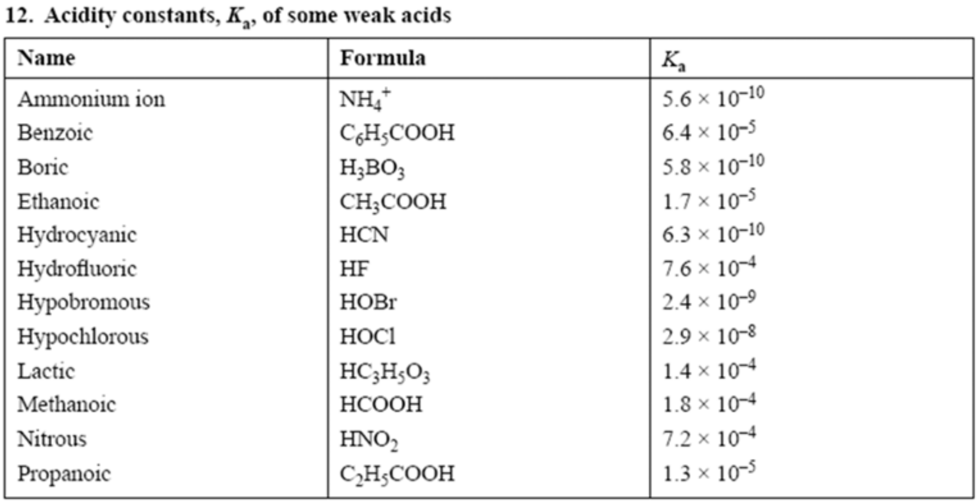
Which of the following describes a solution with a pH=7.0 at 70 °C?

A. acidic
B. basic
C. neutral
D. none of the above

$[H^+] = 10^{-pH} = 10^{-7}$ M
At higher temperatures K_w increases, so $K_w > 10^{-14}$
⇨ $[H^+]x[OH^-] > 10^{-14}$
⇨ $[OH^-] > 10^{-14}/[H^+]$
⇨ $[OH^-] > 10^{-14}/ 10^{-7}$
⇨ $[OH^-] > 10^{-7}$
⇨ $[OH^-] > [H^+]$
⇨ the solution is basic!

UNIT 4 CHEMISTRY– AOS1
Acidity Constants, K_a

- KEY IDEAS:
  - K_a expresses the extent of ionisation of an acid
  - calculations only for weak acids that remain largely un-ionised
    - very low K_a values



12. Acidity constants, K_a, of some weak acids

Name	Formula	K_a
Ammonium ion	NH_4^+	5.6×10^{-10}
Benzoic	C_6H_5COOH	6.4×10^{-5}
Boric	H_3BO_3	5.8×10^{-10}
Ethanoic	CH_3COOH	1.7×10^{-5}
Hydrocyanic	HCN	6.3×10^{-10}
Hydrofluoric	HF	7.6×10^{-4}
Hypobromous	$HOBr$	2.4×10^{-9}
Hypochlorous	$HOCl$	2.9×10^{-8}
Lactic	$HC_3H_5O_3$	1.4×10^{-4}
Methanoic	$HCOOH$	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	C_2H_5COOH	1.3×10^{-5}

UNIT 4 CHEMISTRY– AOS1
Industrial Process

AMMONIA, ETHENE, SULFURIC ACID, or NITRIC ACID

- Learn ONE process *in detail*
- Raw Materials (and their sources)
- Equations including reaction details and conditions

eg for H_2SO_4 (Contact Process)

- Burner:

  $S(l) + O_2(g) \rightarrow SO_2(g)$

  - exothermic, redox (S oxidised 0→+4)
  - molten sulfur sprayed into furnace

- Converter:

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

  - exothermic, redox (S oxidised +4→+6)
  - ~400-500 °C; ~1 atm
  - multiple passes over V_2O_5 catalyst

- Absorption:

  $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

  - product is *oleum*
  - exothermic, not redox
  - avoids problems caused by excessive heat from direct mixing with water

- Dilution:

  $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

  - exothermic, not redox

UNIT 4 CHEMISTRY– AOS1 Industrial Process

Rate and Equilibrium considerations, especially *compromises*

- eg in sulfuric acid production, in the converter:

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

- exothermic reaction ⇨ high yield at *lower temperatures*
- higher rate obtained at *higher temperature*
  - **~450 °C used is a compromise**

- fewer product particles ⇨ high yield at *higher pressure*
- higher rate obtained at *higher pressure*
  - **high pressure gives favourable yield and rate BUT ~1 atm used is a compromise with *cost***

- *catalyst* is important in obtaining adequate rate
- multiple passes over catalyst (with cooling between) to maximise conversion to product

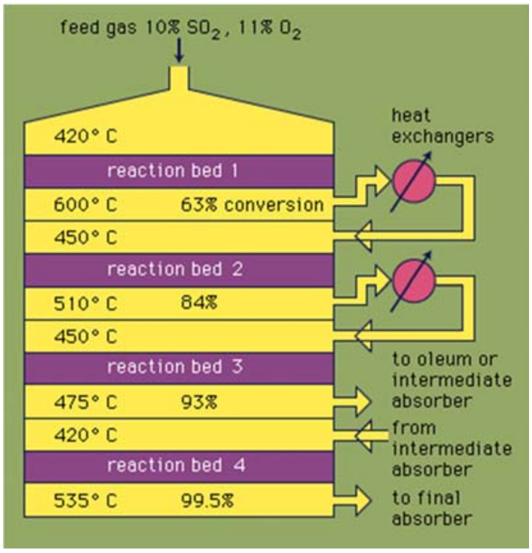


Image: BRITANNICA.COM

UNIT 4 CHEMISTRY– AOS1 Industrial Process

- For properties and uses, make sure you can provide specific *examples*, with *equations* where necessary
- Again, using sulfuric acid as an example:

PROPERTIES

- strong, diprotic acid

$H_2SO_4(aq) \rightarrow HSO_4^-(aq) + H^+(aq)$

$HSO_4^-(aq) \leftrightarrows SO_4^{2-}(aq) + H^+(aq)$

- oxidant

$2H_2SO_4(l) + Mg(s) \rightarrow MgSO_4(aq) + SO_2(g) + 2H_2O(l)$

- dehydrating agent

$C_6H_{12}O_6(s) \rightarrow 6C(s) + 6H_2O(g)$

USES, eg

- fertiliser production

$H_2SO_4(l) + 2NH_3(g) \rightarrow (NH_4)_2SO_4(s)$

  - source of sulfate ions in a range of fertilisers

- removal of metal oxides

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

UNIT 4 CHEMISTRY– AOS1
Waste Management

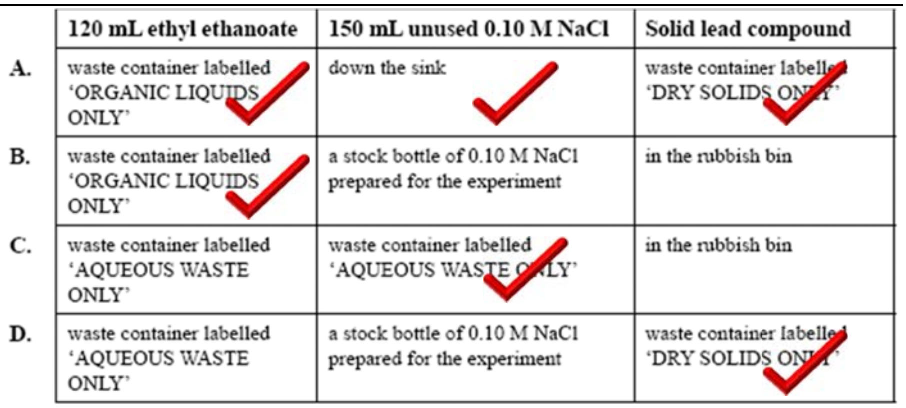
- Methods of waste handling and disposal will depend on
  - the hazards associated with the material
    - explosive
    - toxic
    - carcinogenic
    - corrosive, etc
  - the properties of the material
    - water solubility
    - volatility
    - reactivity
    - stability, etc
- Methods of waste management include
  - modifying procedures to reduce or eliminate wastes
  - recycling of wastes
  - treatment of wastes to reduce hazards
  - disposal of wastes

UNIT 4 CHEMISTRY– AOS1
Waste Management

- …, a chemist was left with several materials to be disposed of in a safe manner. These included

i. 120 mL of ethyl ethanoate	*organic ester; not water soluble*
ii. 150 mL unused 0.10 M NaCl	*soluble ionic compound; common & safe*
iii. a solid compound of lead … dried and weighed on filter paper.	*heavy metal – toxic; solid*

Which one of the following alternatives describes an appropriate method of disposal of each of the above wastes …?



	120 mL ethyl ethanoate	150 mL unused 0.10 M NaCl	Solid lead compound
A.	waste container labelled 'ORGANIC LIQUIDS ONLY' ✓	down the sink ✓	waste container labelled 'DRY SOLIDS ONLY' ✓
B.	waste container labelled 'ORGANIC LIQUIDS ONLY' ✓	a stock bottle of 0.10 M NaCl prepared for the experiment	in the rubbish bin
C.	waste container labelled 'AQUEOUS WASTE ONLY'	waste container labelled 'AQUEOUS WASTE ONLY' ✓	in the rubbish bin
D.	waste container labelled 'AQUEOUS WASTE ONLY'	a stock bottle of 0.10 M NaCl prepared for the experiment	waste container labelled 'DRY SOLIDS ONLY' ✓

2008 Unit 4, Question 13

AREA OF STUDY 2

SUPPLYING & USING ENERGY

UNIT 4 CHEMISTRY– AOS2
STUDY DESIGN – KEY KNOWLEDGE

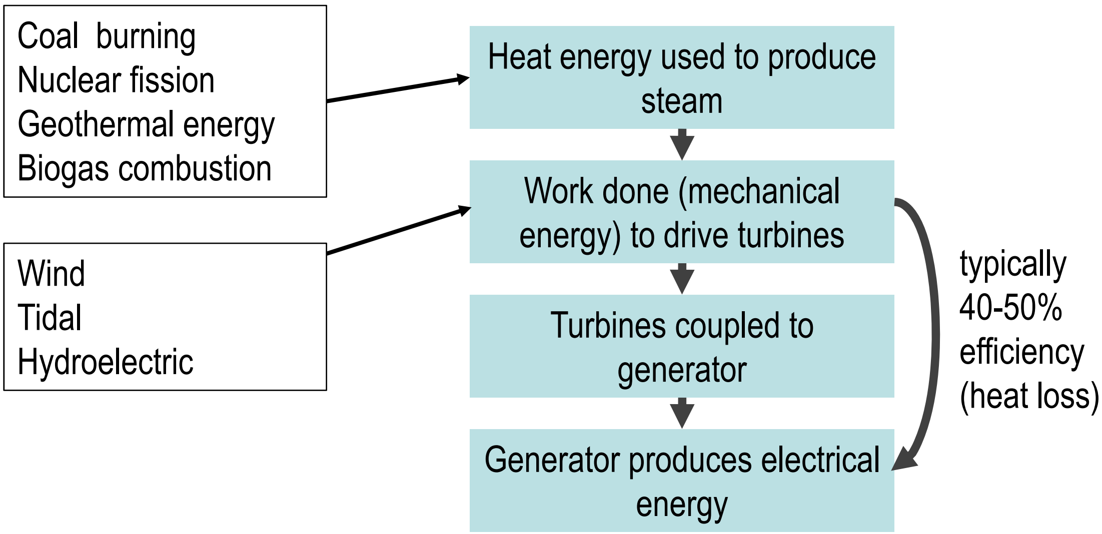
- comparison of energy sources: types, uses and sustainability of sources including brown coal, natural gas, nuclear fission and biochemical fuels;
- application of calorimetry to measure energy changes in chemical reactions in solution calorimetry and bomb calorimetry;
- use of the electrochemical series in predicting the products of redox reactions and writing half equations;
- limitations of predictions made using the electrochemical series;
- the construction and operation of simple galvanic primary and secondary cells;
- the construction and operation of fuel cells: advantages and disadvantages of fuel cells compared to conventional energy sources;
- the construction and operation of simple electrolytic cells: comparison of electrolytic cells;
- application of Faraday’s laws in electrochemistry.

UNIT 4 CHEMISTRY– AOS2
Comparison of Energy Sources

Little on recent exams but definitely KEY KNOWLEDGE in Study Design:

> *"comparison of energy sources: types, uses and sustainability of sources including brown coal, natural gas, nuclear fission and biochemical fuels"*

The following energy transformation associated with Power Plants is generally important:



Coal burning
Nuclear fission
Geothermal energy
Biogas combustion

Wind
Tidal
Hydroelectric

Heat energy used to produce steam

Work done (mechanical energy) to drive turbines

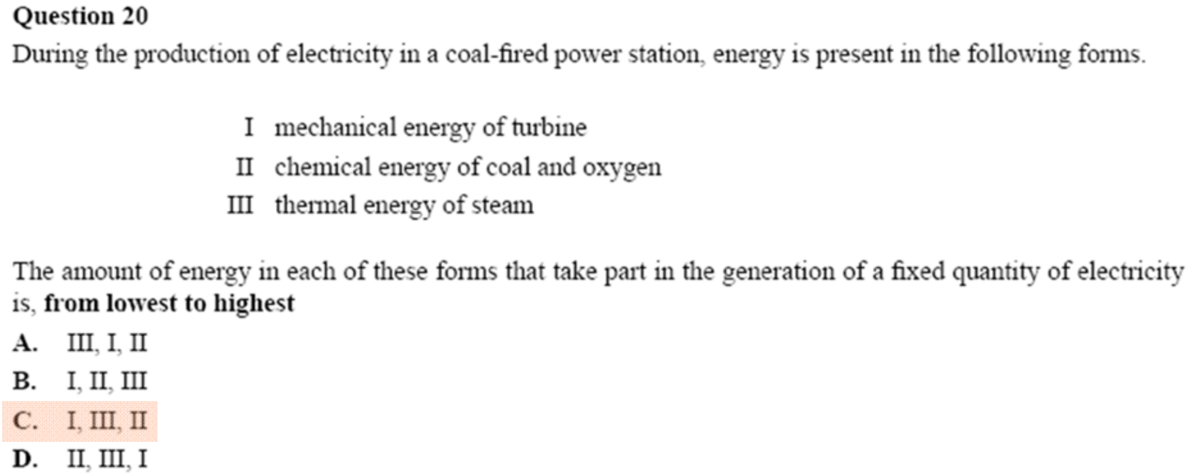
Turbines coupled to generator

Generator produces electrical energy

typically 40-50% efficiency (heat loss)

UNIT 4 CHEMISTRY– AOS2
Comparison of Energy Sources

- From 2007 Unit 4



Question 20

During the production of electricity in a coal-fired power station, energy is present in the following forms.

I mechanical energy of turbine
II chemical energy of coal and oxygen
III thermal energy of steam

The amount of energy in each of these forms that take part in the generation of a fixed quantity of electricity is, **from lowest to highest**

A. III, I, II
B. I, II, III
C. I, III, II
D. II, III, I

energy is lost at each stage:

II chemical energy (coal/oxygen) → III thermal energy (steam) → I mechanical energy (turbine/generator) → electrical energy

UNIT 4 CHEMISTRY– AOS2
Calorimetry

CALIBRATION

- A calorimeter is a calibrated ‘black box’
- A calorimeter’s calibration factor relates
  - a temperature change (measurable)
  - a corresponding energy change (not directly measurable)
- calibration involves
  1. Adding a known quantity of energy
     - using an electric heater: $E=VIt$
     - using a known reaction: $E=n \times$ (molar heat of reaction)
  2. Measuring the corresponding temperature change
  3. Calculating the ratio

$$\text{calibration factor} = \frac{\text{energy added}}{\text{temperature change}}$$

UNIT 4 CHEMISTRY– AOS2
Solution Calorimetry

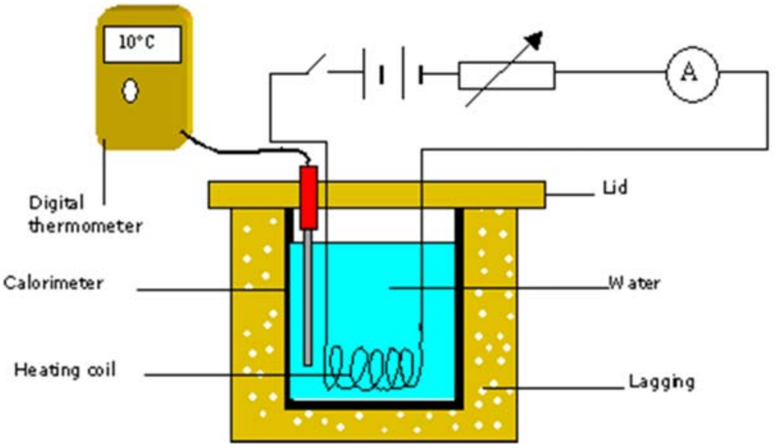


Diagram from www.seai.ie/Schools/Secondary_Schools/Subjects/Physics/Unit_4_-_Electric_Effects/Joule's_Law/

KEY COMPONENTS:

- insulated container
- thermometer
- *fixed* volume of water or aqueous solution

OFTEN INCLUDE:

- stirrer
- heating coil for calibration

used for any reactions in the aqueous phase, eg

- acid + base
- heat of solution (ie dissolving)

UNIT 4 CHEMISTRY– AOS2
Bomb Calorimetry

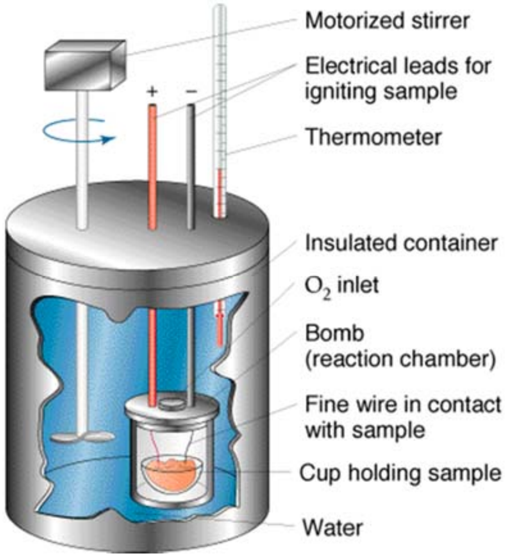


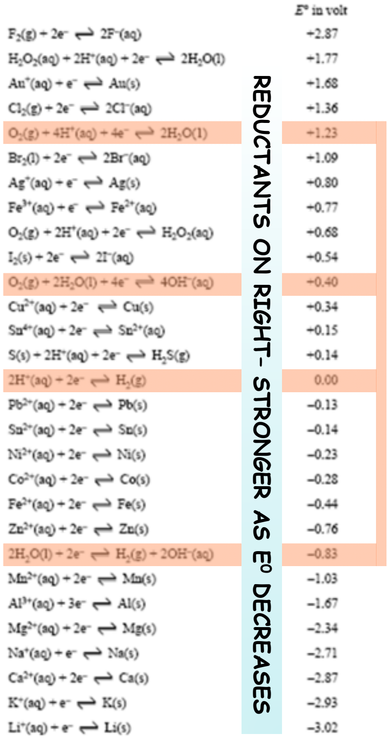
Diagram: www.chem.ufl.edu/~itl/2045/lectures/lec_9.html

KEY COMPONENTS:
- insulated container
- thermometer
- *fixed* volume of water
- enclosed reaction chamber (the ‘bomb’)
- ignition wire to start reaction
- stirrer

CAN INCLUDE:
- heating coil for calibration

used for non-aqueous reactions
- combustion of fuels (very important)
- decomposition (eg explosives)

UNIT 4 CHEMISTRY– AOS2
Electrochemical Series



	E° in volt
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	−0.23
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	−0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.03
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	−1.67
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.34
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	−2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.02

OXIDANTS ON LEFT – STRONGER AS E^0 INCREASES

REDUCTANTS ON RIGHT– STRONGER AS E^0 DECREASES

Key reactions involving water, oxygen and hydrogen

- KEY IDEAS

•Each line represents a redox *equilibrium*

•E^0 values relates to the equilibrium constant, K, for a redox reaction

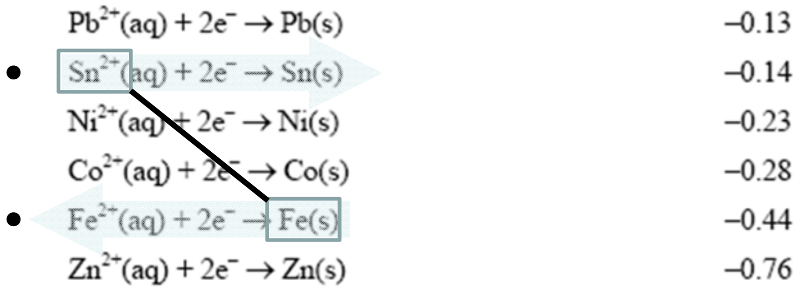
- with very large (+) E^0 values (top)
  - the equilibrium lies heavily to the right
  - strong tendency for oxidant to gain e^-
- with very small (-) E^0 values (bottom)
  - the equilibrium lies heavily to the left
  - strong tendency for reductant to lose e^-

•E^0 values are measured against the standard H^+/H_2 half cell

- this is an arbitrary standard

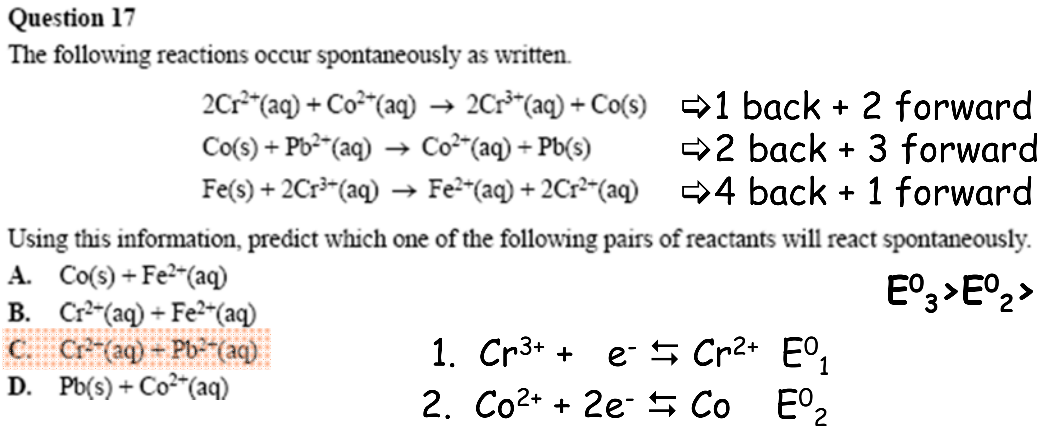
UNIT 4 CHEMISTRY– AOS2
Predicting Spontaneous Reactions

- A USEFUL GENERAL IDEA
  - in any situation where two half-equations are combined
    - the one with the higher E^0 value will go forward
    - the one with the lower E^0 value will go backward
  - for spontaneous reaction we need E^0(oxidant)>E^0(reductant)
  - hence
    - “top left – bottom right”
    - “backward-Z”



$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.23
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76

UNIT 4 CHEMISTRY– AOS2
Predicting Spontaneous Reactions



Question 17

The following reactions occur spontaneously as written.

$2Cr^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + Co(s)$ ⇨1 back + 2 forward ⇨ $E^0_2 > E^0_1$

$Co(s) + Pb^{2+}(aq) \rightarrow Co^{2+}(aq) + Pb(s)$ ⇨2 back + 3 forward ⇨ $E^0_3 > E^0_2$

$Fe(s) + 2Cr^{3+}(aq) \rightarrow Fe^{2+}(aq) + 2Cr^{2+}(aq)$ ⇨4 back + 1 forward ⇨ $E^0_1 > E^0_4$

Using this information, predict which one of the following pairs of reactants will react spontaneously.

A. $Co(s) + Fe^{2+}(aq)$
B. $Cr^{2+}(aq) + Fe^{2+}(aq)$
C. $Cr^{2+}(aq) + Pb^{2+}(aq)$
D. $Pb(s) + Co^{2+}(aq)$

$E^0_3 > E^0_2 > E^0_1 > E^0_4$

1. $Cr^{3+} + e^- \leftrightarrows Cr^{2+}$ E^0_1
2. $Co^{2+} + 2e^- \leftrightarrows Co$ E^0_2
3. $Pb^{2+} + 2e^- \leftrightarrows Pb$ E^0_3
4. $Fe^{2+} + 2e^- \leftrightarrows Fe$ E^0_4

UNIT 4 CHEMISTRY– AOS2
Electrochemical Series - Limitations

- In some circumstances predictions based on the electrochemical series are not borne out in practice
  - reactions may occur that are not predicted
  - reactions that are predicted may apparently not occur

REASON 1: NON-STANDARD CONDITIONS

- E^0 values and hence the order of the electrochemical series hold only for STANDARD CONDITIONS:
  - T = 25 °C
  - c = 1 M for solutions
  - p = 1 atm = 101.3 kPa for gases

REASON 2: EQUILIBRIUM v RATE

- when a *spontaneous reaction* is predicted, this means that the predicted reaction has a *large equilibrium constant* (K is a function of the E^0 difference)
- *no conclusion* can be drawn about the *rate* at which a predicted reaction will occur
  - a predicted reaction may have a very large activation energy and thus be too slow to detect

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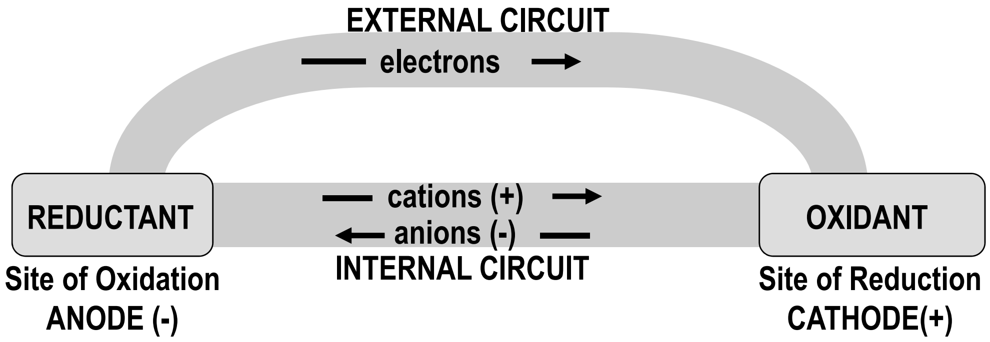
UNIT 4 CHEMISTRY– AOS2
Galvanic Cells

- All functioning galvanic cells comprise an *oxidant* and a *reductant* isolated from each other but connected by
  1. An *external circuit* through which *electrons* are conducted from reductant to oxidant.
  2. An *internal circuit* through which *ions* are conducted. The flow of charge in the internal circuit exactly balances the flow of electrons in the external circuit.
- These features are present in *all* galvanic cells.



EXTERNAL CIRCUIT

— electrons →

REDUCTANT

Site of Oxidation
ANODE (-)

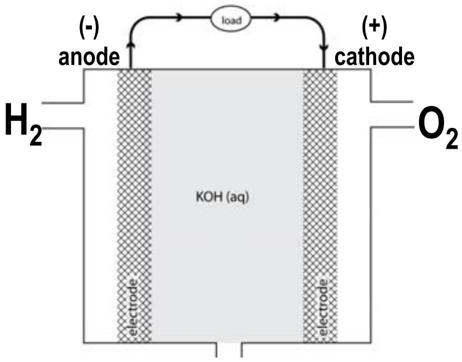
— cations (+) →
← anions (-) —
INTERNAL CIRCUIT

OXIDANT

Site of Reduction
CATHODE(+)

UNIT 4 CHEMISTRY– AOS2
Fuel Cells

- Primary and Secondary cells:
  - reactants are completely enclosed and stored within the cell.
- Fuel cells:
  - reactants continuously supplied from outside the cell.
  - Mainly for *gaseous* reactants, especially oxygen gas as oxidant.
  - Thus fuel cells are used to obtain electrical energy from
    - combustion reactions, where O_2 is reacted with a ***fuel*** (hence the term 'fuel cell')
    - corrosion reactions, where O_2 is reacted with a metal
  - In a typical fuel cell
    - O_2 is reduced at the cathode (+)
    - the 'fuel' eg H_2 is oxidised at the anode (-)



UNIT 4 CHEMISTRY– AOS2
Electrolysis

- Non-spontaneous redox reactions can be forced to progress by the application of an external EMF.
  - A DC power source is used to force electrons
    - *onto* the (-) electrode, coercing reduction (hence cathode)
    - *out of* the (+) electrode, coercing oxidation (hence anode)
  - Applications include
    - recharging secondary cells
    - 'electrowinning' of metals from ores
    - production of useful chemicals (eg Cl_2)
    - electroplating
    - electrorefining to purify metals like copper

- Electrode reactions can be predicted from the electrochemical series
  - list all possible oxidants – the strongest (highest E^0) will react
  - list all possible reductants – the strongest (lowest E^0) will react
  - remember that the solvent (H_2O) and the electrode materials must be considered as candidates

UNIT 4 CHEMISTRY– AOS2
Faraday’s Laws

- Essentially just STOICHIOMETRY calculations
  - using half-equations to establish mole-ratios for electrons
  - using n = Q/F to calculate amount (moles) of electrons

2004 Question 9

96.5 C of electricity is used to completely deposit silver metal (Ag) from an aqueous solution [of] $Ag^{+}(aq)$. Another 96.5 C is used to completely deposit copper (Cu) from an aqueous solution [of] $Cu^{2+}(aq)$.

The silver metal deposited would

A. have half the mass of the copper deposited.
B. have twice the mass of the copper deposited.
C. be half the mole of the copper deposited.
D. be twice the mole of the copper deposited.

- $n(e^-) = Q/F = 96.5/96500 = 0.001$ mol
- $n(Ag) = n(e^-) = 0.001$ mol ⇨ $m(Ag) = nM = 0.001 \times 107.9 = 0.108$ g
- $n(Cu) = \frac{1}{2} \times n(e^-) = 0.0005$ mol ⇨ $m(Cu) = nM = 0.0005 \times 63.5 = 0.0318$ g

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CHANGE OF PREFERENCE 16-21 DECEMBER

DROP INTO VUHQ - CITY FLINDERS CAMPUS, ONLINE CHAT SERVICE & COURSE HOTLINE: 1300 VIC UNI

Friday 16	8:30AM - 5:30PM
Saturday 17	11:00AM - 4:00PM
Sunday 18	11:00AM - 4:00PM
Monday 19	8:30AM - 5:30PM
Tuesday 20	8:30AM - 5:30PM

GENERAL INFORMATION SESSIONS

Monday 19	4:00PM - 7:00PM
Tuesday 20	4:00PM - 7:00PM

Footscray Park Campus
Ballarat Road, Footscray
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