

IB Diploma

# CHEMISTRY

SL

Paper 2

2017 — 2023

Chapter 1	<b>Stoichiometric Relationship</b>	Page 1
Chapter 2	<b>Atomic Structure</b>	Page 67
Chapter 3	<b>Periodicity</b>	Page 104
Chapter 4	<b>Chemical Bonding &amp; Structure</b>	Page 131
Chapter 5	<b>Energetics / Thermochemistry</b>	Page 179
Chapter 6	<b>Chemical Kinetics</b>	Page 230
Chapter 7	<b>Equilibrium</b>	Page 270
Chapter 8	<b>Acids &amp; Bases</b>	Page 298
Chapter 9	<b>Redox Processes</b>	Page 341
Chapter 10	<b>Organic Chemistry</b>	Page 379
Chapter 11	<b>Measurement &amp; Data Processing</b>	Page 433
	<b>Answers</b>	Page 466

1 - (CHEMI/21\_SL\_Summer\_2017\_Q2) - Chemical Bonding & Structure, Stoichiometric Relationship, Atomic Structure

Titanium is a transition metal.

(a) Describe the bonding in metals.

[2]

(b) Titanium exists as several isotopes. The mass spectrum of a sample of titanium gave the following data:

Mass number	% abundance
46	7.98
47	7.32
48	73.99
49	5.46
50	5.25

Calculate the relative atomic mass of titanium to two decimal places.

[2]

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(c) State the number of protons, neutrons and electrons in the  ${}^{48}_{22}\text{Ti}$  atom.

[1]

Protons:  
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Neutrons:  
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Electrons:  
.....

- (d) (i) State the full electron configuration of the  ${}_{22}^{48}\text{Ti}^{2+}$  ion. [1]

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- (ii) Explain why an aluminium-titanium alloy is harder than pure aluminium. [2]

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- (e) (i) State the type of bonding in potassium chloride which melts at 1043 K. [1]

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- (ii) A chloride of titanium,  $\text{TiCl}_4$ , melts at 248 K. Suggest why the melting point is so much lower than that of KCl. [1]

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- (f)  $\text{TiCl}_4$  reacts with water and the resulting titanium(IV) oxide can be used as a smoke screen.

- (i) Formulate an equation for this reaction. [2]

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- (ii) Suggest one disadvantage of using this smoke in an enclosed space. [1]

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2 - (CHEMI/22\_SL\_Summer\_2017\_Q1) - Stoichiometric Relationship, Atomic Structure

There are many oxides of silver with the formula  $\text{Ag}_x\text{O}_y$ . All of them decompose into their elements when heated strongly.

- (a) (i) After heating 3.760 g of a silver oxide 3.275 g of silver remained. Determine the empirical formula of  $\text{Ag}_x\text{O}_y$ . [2]

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- (ii) Suggest why the final mass of solid obtained by heating 3.760 g of  $\text{Ag}_x\text{O}_y$  may be greater than 3.275 g giving one design improvement for your proposed suggestion. Ignore any possible errors in the weighing procedure. [2]

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- (b) Naturally occurring silver is composed of two stable isotopes,  $^{107}\text{Ag}$  and  $^{109}\text{Ag}$ .

The relative atomic mass of silver is 107.87. Show that isotope  $^{107}\text{Ag}$  is more abundant. [1]

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- (c) (i) Some oxides of period 3, such as  $\text{Na}_2\text{O}$  and  $\text{P}_4\text{O}_{10}$ , react with water. A spatula measure of each oxide was added to a separate  $100\text{ cm}^3$  flask containing distilled water and a few drops of bromothymol blue indicator. The indicator is listed in section 22 of the data booklet.

Deduce the colour of the resulting solution and the chemical formula of the product formed after reaction with water for each oxide. [3]

Flask containing	Colour of solution	Product formula
$\text{Na}_2\text{O}$	.....	.....
$\text{P}_4\text{O}_{10}$	.....	.....

- (ii) Explain the electrical conductivity of molten  $\text{Na}_2\text{O}$  and  $\text{P}_4\text{O}_{10}$ . [2]

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- (d) Outline the model of electron configuration deduced from the hydrogen line emission spectrum (Bohr's model). [2]

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## 3 - (CHEMI/22\_SL\_Summer\_2017\_Q2) - Redox Processes, Stoichiometric Relationship

An acidic sample of a waste solution containing  $\text{Sn}^{2+}(\text{aq})$  reacted completely with  $\text{K}_2\text{Cr}_2\text{O}_7$  solution to form  $\text{Sn}^{4+}(\text{aq})$ .

- (a) (i) State the oxidation half-equation. [1]

.....

- (ii) Deduce the overall redox equation for the reaction between acidic  $\text{Sn}^{2+}(\text{aq})$  and  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ , using section 24 of the data booklet. [1]

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- (b) (i) Calculate the percentage uncertainty for the mass of  $\text{K}_2\text{Cr}_2\text{O}_7(\text{s})$  from the given data. [1]

Mass of weigh boat / $\text{g} \pm 0.001 \text{ g}$	1.090
Mass of weigh boat + $\text{K}_2\text{Cr}_2\text{O}_7(\text{s})$ / $\text{g} \pm 0.001 \text{ g}$	14.329

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- (ii) The sample of  $\text{K}_2\text{Cr}_2\text{O}_7(\text{s})$  in (i) was dissolved in distilled water to form  $0.100 \text{ dm}^3$  solution. Calculate its molar concentration. [1]

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- (iii) 10.0 cm<sup>3</sup> of the waste sample required 13.24 cm<sup>3</sup> of the K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution.  
Calculate the molar concentration of Sn<sup>2+</sup> (aq) in the waste sample.

[2]

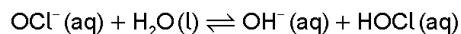
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## 4 - (CHEMI/22\_SL\_Summer\_2017\_Q7) - Acids &amp; Bases, Stoichiometric Relationship

Soluble acids and bases ionize in water.

(a) Sodium hypochlorite ionizes in water.



(i) Identify the amphiprotic species. [1]

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(ii) Identify one conjugate acid-base pair in the reaction. [1]

Acid	Base
.....	.....

(b) A solution containing 0.510 g of an unknown monoprotic acid, HA, was titrated with 0.100 mol dm<sup>-3</sup> NaOH (aq). 25.0 cm<sup>3</sup> was required to reach the equivalence point.

(i) Calculate the amount, in mol, of NaOH (aq) used. [1]

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(ii) Calculate the molar mass of the acid. [1]

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(iii) Calculate [H<sup>+</sup>] in the NaOH solution. [1]

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# ANSWERS

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## 1 - (CHEMI/21\_SL\_Summer\_2017\_Q2) - Chemical Bonding &amp; Structure, Stoichiometric Relationship, Atomic Structure

a		electrostatic attraction ✓ between «a lattice of» metal/positive ions/cations AND «a sea of» delocalized electrons ✓	Accept mobile electrons. Do not accept "metal atoms/nuclei".	2
b		$\frac{(46 \times 7.98) + (47 \times 7.32) + (48 \times 73.99) + (49 \times 5.46) + (50 \times 5.25)}{100}$ ✓ = 47.93 ✓	Answer must have two decimal places with a value from 47.90 to 48.00. Award [2] for correct final answer. Award [0] for 47.87 (data booklet value).	2
c		Protons: 22 AND Neutrons: 26 AND Electrons: 22 ✓		1
d	i	1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>2</sup> ✓		1
d	ii	titanium atoms/ions distort the regular arrangement of atoms/ions OR titanium atoms/ions are a different size to aluminium «atoms/ions» ✓  prevent layers sliding over each other ✓	Accept diagram showing different sizes of atoms/ions.	2
e	i	ionic OR «electrostatic» attraction between oppositely charged ions ✓		1
e	ii	«simple» molecular structure OR weak«er» intermolecular bonds OR weak«er» bonds between molecules ✓	Accept specific examples of weak bonds such as London/dispersion and van der Waals. Do not accept "covalent".	1
f	i	TiCl <sub>4</sub> (l) + 2H <sub>2</sub> O (l) → TiO <sub>2</sub> (s) + 4HCl (aq) correct products ✓ correct balancing ✓	Accept ionic equation. Award M2 if products are HCl and a compound of Ti and O.	2
f	ii	HCl causes breathing/respiratory problems OR HCl is an irritant OR HCl is toxic OR HCl has acidic vapour OR HCl is corrosive ✓	Accept "TiO <sub>2</sub> causes breathing problems/is an irritant". Accept "harmful" for both HCl and TiO <sub>2</sub> . Accept "smoke is asphyxiant".	1

## 2 - (CHEMI/22\_SL\_Summer\_2017\_Q1) - Stoichiometric Relationship, Atomic Structure

a	i	$n(\text{Ag}) = \frac{3.275 \text{ g}}{107.87 \text{ g mol}^{-1}} \Rightarrow 0.03036 \text{ «mol»}$  AND $n(\text{O}) = \frac{3.760 \text{ g} - 3.275 \text{ g}}{16.00 \text{ g mol}^{-1}} = \frac{0.485}{16.00} \Rightarrow 0.03031 \text{ «mol»} \checkmark$  $\frac{0.03036}{0.03031} \approx 1 / \text{ratio of Ag to O approximately } 1 : 1, \text{ so}$ AgO ✓	Accept other valid methods for M1.  Award [1 max] for correct empirical formula if method not shown.	2
a	ii	temperature too low OR heating time too short OR oxide not decomposed completely ✓  heat sample to constant mass «for three or more trials» ✓	Accept "not heated strongly enough".  If M1 as per markscheme, M2 can only be awarded for constant mass technique.  Accept "soot deposition" (M1) and any suitable way to reduce it (for M2).  Accept "absorbs moisture from atmosphere" (M1) and "cool in dessicator" (M2).  Award [1 max] for reference to impurity AND design improvement.	2
b		A <sub>r</sub> closer to 107/less than 108 «so more <sup>107</sup> Ag» OR A <sub>r</sub> less than the average of (107 + 109) «so more <sup>107</sup> Ag» ✓	Accept calculations that gives greater than 50% <sup>107</sup> Ag.	1

c	i	Flask containing	Colour of solution	Product formula	Do not accept name for the products. Accept "Na <sup>+</sup> + OH <sup>-</sup> " for NaOH.  Ignore coefficients in front of formula.	3
		Na <sub>2</sub> O	blue	NaOH ✓		
		P <sub>4</sub> O <sub>10</sub>	AND yellow ✓	H <sub>3</sub> PO <sub>4</sub> ✓		
c	ii	«molten» Na <sub>2</sub> O has mobile ions/charged particles AND conducts electricity ✓ «molten» P <sub>4</sub> O <sub>10</sub> does not have mobile ions/charged particles AND does not conduct electricity/is poor conductor of electricity ✓			Do not award marks without concept of mobile charges being present.  Award [1 max] if type of bonding or electrical conductivity correctly identified in each compound.  Do not accept answers based on electrons.  Award [1 max] if reference made to solution.	2
d		electrons in discrete/specific/certain/different shells/energy levels ✓ energy levels converge/get closer together at higher energies <b>OR</b> energy levels converge with distance from the nucleus ✓			Accept appropriate diagram for M1, M2 or both.  Do not give marks for answers that refer to the lines in the spectrum.	2

## 3 - (CHEMI/22\_SL\_Summer\_2017\_Q2) - Redox Processes, Stoichiometric Relationship

a	i	Sn <sup>2+</sup> (aq) → Sn <sup>4+</sup> (aq) + 2e <sup>-</sup> ✓	Accept equilibrium sign. Accept Sn <sup>2+</sup> (aq) - 2e <sup>-</sup> → Sn <sup>4+</sup> (aq).	1
a	ii	Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup> (aq) + 14H <sup>+</sup> (aq) + 3Sn <sup>2+</sup> (aq) → 2Cr <sup>3+</sup> (aq) + 7H <sub>2</sub> O (l) + 3Sn <sup>4+</sup> (aq) ✓	Accept equilibrium sign.	1
b	i	«13.239 g ± 0.002 g so percentage uncertainty» 0.02 «%» ✓	Accept answers given to greater precision, such as 0.0151 %.	1
b	ii	« [K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> ] = $\frac{13.239 \text{ g}}{294.20 \text{ g mol}^{-1} \times 0.100 \text{ dm}^3} \Rightarrow 0.450 \text{ «mol dm}^{-3}\text{»} \checkmark$		1
b	iii	n(Sn <sup>2+</sup> ) = «0.450 mol dm <sup>-3</sup> × 0.01324 dm <sup>3</sup> × $\frac{3 \text{ mol}}{1 \text{ mol}} \Rightarrow 0.0179 \text{ «mol»} \checkmark$ «[Sn <sup>2+</sup> ] = $\frac{0.0179 \text{ mol}}{0.0100 \text{ dm}^3} \Rightarrow 1.79 \text{ «mol dm}^{-3}\text{»} \checkmark$	Award [2] for correct final answer.	2

## 4 - (CHEMI/22\_SL\_Summer\_2017\_Q7) - Acids &amp; Bases, Stoichiometric Relationship

a	i	water/H <sub>2</sub> O ✓	Accept "hydroxide ion/OH <sup>-</sup> ".	1
a	ii	Acid	Base	1
		HOCl AND OR H <sub>2</sub> O AND	OCl <sup>-</sup> OH <sup>-</sup> ✓	
b	i	«0.100 mol dm <sup>-3</sup> × 0.0250 dm <sup>3</sup> » = 0.00250 «mol» ✓		1
b	ii	«M = $\frac{0.510 \text{ g}}{0.00250 \text{ mol}} \Rightarrow 204 \text{ «g mol}^{-1}\text{»} \checkmark$		1
b	iii	«1.00 × 10 <sup>-14</sup> = [H <sup>+</sup> ] × 0.100» 1.00 × 10 <sup>-13</sup> «mol dm <sup>-3</sup> » ✓		1