Chemistry Stage 3

Semester One Examination, 2012

Question/Answer Booklet

NAME: SOLUTIONS

TEACHER: ______________________

Marker use only

Part	Marks achieved	Marks available
1 Multiple choice	/50	50 (33%)
2 Short answer	/60	60 (40%)
3 Extended answers	/40	40 (27%)
TOTAL		150 (100%)

%

Time allowed for this paper
Reading time before commencing work: Ten minutes
Working time for paper: Two and a half hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Separate Multiple Choice Answer Sheet
Separate Chemistry Data Sheet

To be provided by the candidate
Standard Items: Pens, pencils, eraser or correction fluid and ruler
Special Items: A 2B, B or HB pencil for the separate Multiple Choice Answer Sheet and calculators satisfying the conditions set by the Curriculum Council for this subject.

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Chemistry 3AB Examination

Semester 1 2012

NAME : SOLUTIONS

TEACHER : ____________________

MULTIPLE CHOICE ANSWER SHEET

1.	[A]	~~[B]~~	[C]	[D]	16.	[A]	[B]	[C]	~~[D]~~
2.	[A]	[B]	[C]	~~[D]~~	17.	[A]	[B]	[C]	~~[D]~~
3.	[A]	[B]	~~[C]~~	[D]	18.	~~[A]~~	[B]	[C]	[D]
4.	[A]	[B]	[C]	~~[D]~~	19.	~~[A]~~	[B]	[C]	[D]
5.	~~[A]~~	[B]	[C]	[D]	20.	[A]	[B]	~~[C]~~	[D]
6.	[A]	[B]	~~[C]~~	[D]	21.	[A]	[B]	~~[C]~~	[D]
7.	[A]	[B]	[C]	~~[D]~~	22.	~~[A]~~	[B]	[C]	[D]
8.	[A]	~~[B]~~	[C]	[D]	23.	[A]	[B]	[C]	~~[D]~~
9.	[A]	~~[B]~~	[C]	[D]	24.	[A]	[B]	~~[C]~~	[D]
10.	~~[A]~~	[B]	[C]	[D]	25.	[A]	[B]	~~[C]~~	[D]
11.	[A]	[B]	~~[C]~~	[D]					
12.	[A]	[B]	~~[C]~~	[D]					
13.	[A]	[B]	~~[C]~~	[D]					
14.	~~[A]~~	[B]	[C]	[D]					
15.	[A]	[B]	[C]	~~[D]~~					

________/ 25 marks

PART 2 (60 marks)

Answer **ALL** questions in Part 2 in the spaces provided below.

Question 26.

Give fully balanced equations for the reactions which occur (if at all) in the following experiments.

Use **ionic equations** where appropriate. In each case describe observations such as colour changes, precipitate formation (give the colour), or gas evolution (give the colour or describe as colourless) resulting from the chemical reaction.

(a) Copper (II) nitrate solution is added to sodium carbonate solution.

Equation $Cu^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CuCO_{3(s)}$

[2 marks]

Observation A clear blue solution and a clear colourless solution are mixed forming a green precipitate

[1 mark]

(b) Barium hydroxide solution is added to diluted hydrochloric acid.

Equation $OH^-_{(aq)} + H^+_{(aq)} \rightarrow H_2O_{(l)}$

[2 marks]

Observation Two clear and colourless solutions are mixed, no visible reaction is observed.

[1 mark]

(c) Sodium metal is added to water.

Equation $2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2Na^+_{(aq)} + 2OH^-_{(aq)} + H$

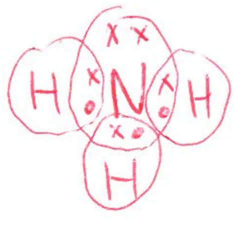
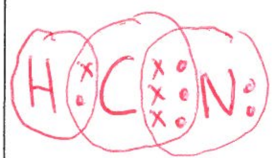
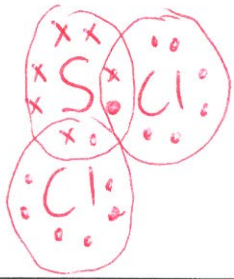
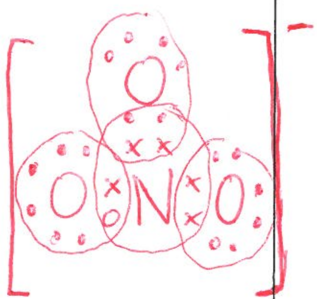
[2 marks]

Observation A shiny, silver metal is placed into a clear, colourless liquid, violent fizzing with metal moving over surface, a clear, colourless, odourless gas evolved and a clear colourless solution remains.

[1 mark]

Question 27.

Complete the table below by drawing correct Lewis (electron dot) diagrams, the molecular shape, indicating whether the substance is polar or non polar.

Formula	Lewis (electron dot) diagram	Name of molecule shape	Polar or non polar
NH_3		pyramidal	polar
HCN		linear	Polar
SCl_2		V - shaped (bent)	Polar
NO_3^-		trigonal planar	Not required

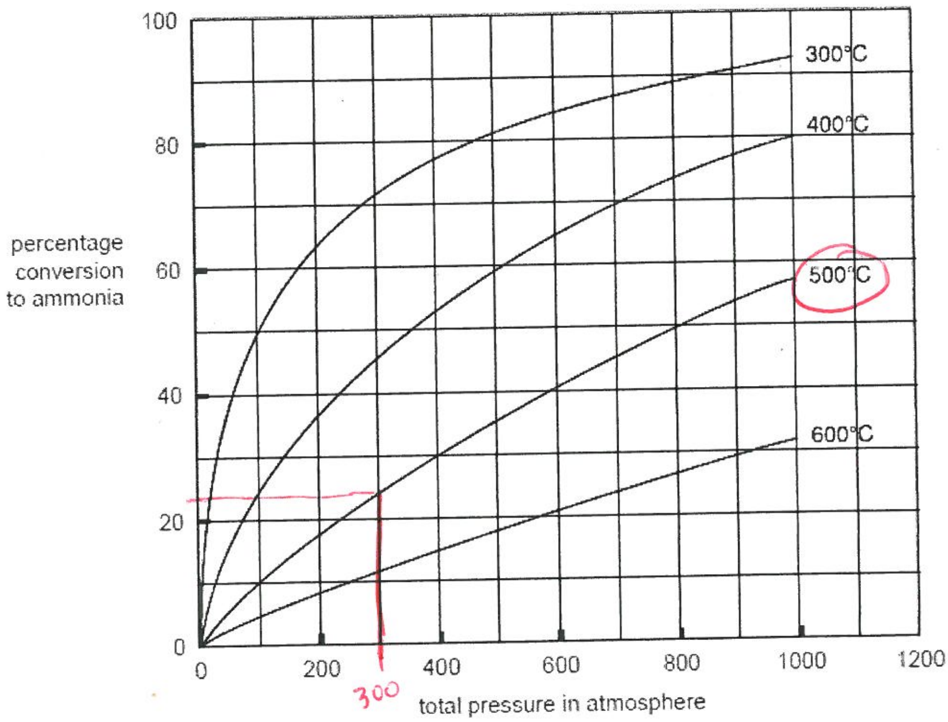
[11 marks]

Question 28.

Ammonia is prepared industrially from hydrogen and nitrogen in the presence of a suitable catalyst according to the equation

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

The graph below shows the variation of the equilibrium yield of ammonia with pressure at different temperatures.



(a) A particular industrial plant uses a pressure of 300 atm and a temperature of 500°C. From the graph, determine the percentage yield of ammonia under these conditions.

≈ 24%

[1 mark]

(b) State Le Chatelier's principle.

If a chemical system at equilibrium is subjected to a change in conditions, the system will adjust to re-establish equilibrium in such a way as to partially counteract the imposed change.

[2 marks]

(c) Deduce from the graph whether the production of ammonia from hydrogen and nitrogen is an exothermic or an endothermic reaction. Explain your reasoning.

- For a given pressure there is a greater yield of ammonia at lower temperatures.
- This indicates an exothermic reaction as the lower temperatures would favour product formation. (and release of heat to surroundings)

[2 marks]

(d) Temperatures less than 400°C are not used for this industrial reaction even though such temperatures give a greater equilibrium yield of ammonia. Give a possible reason why this is so.

Dispite the larger yields for temperatures lower than 400°C, the reaction rate would be too slow to be economical (Take too long)

[2 marks]

Question 29.

Consider the following chemical substances.

CO_2 SO_3 NH_3 H_2O N_2 S_8 Cl_2 CCl_4

List all the molecules that contain polar bond.	CO_2 SO_3 NH_3 H_2O CH_4
List all the polar molecules	NH_3 H_2O
List all linear molecules	CO_2 N_2 Cl_2

(Note: Substances can be listed in more than one category)

[6 marks]

* note SO_3 is trigonal planar and non-polar.

Question 30.

On Earth, water evaporates, forms clouds and falls back to the ground in a process known as the 'water cycle'.

On Saturn's moon Titan, where the average temperature is 94 K (-178°C), methane behaves in the same way as water does on Earth, evaporating and raining onto the surface as a liquid.

Using your knowledge of their structure and bonding, explain why water and methane undergo these processes at such different temperatures.

- On Earth the average temperature is moderate $\approx 25^{\circ}C$. At this temperature water can be a liquid due to its strong intermolecular forces (hydrogen bonds) but the methane is a gas with weaker forces (dispersion only).

- On Titan the average temperature is much lower which allows methane to condense to a liquid with its weak dispersion forces. This would not be possible on Earth as the higher average temperature gives particle ample energy to remain a gas.

[4 marks]

Question 31.

The following equilibrium is being investigated:

$$2ZnS_{(s)} + 3O_{2(g)} \rightleftarrows 2ZnO_{(s)} + 2SO_{2(g)} \qquad \Delta H = -879 \text{ kJ}$$

Three identical sealed boxes are set up, each containing the equilibrium mixture. Each of the boxes is treated as described below, and time is allowed for a new equilibrium to be established. In each case describe the change between the original equilibrium and new equilibrium.

Treatment	What happens to the rate of the forward reaction? Write 'increase', 'decrease' or 'no change'	What happens to the equilibrium position? Write 'move to the right', 'move to the left' or 'no change'
A small amount of $O_{2(g)}$ is added.	Increase	move to the right
$Ne_{(g)}$ is pumped in, increasing the pressure of the system (no volume change).	No change	No change
The reaction vessel is heated.	Increases *	move to the left

[6 marks]

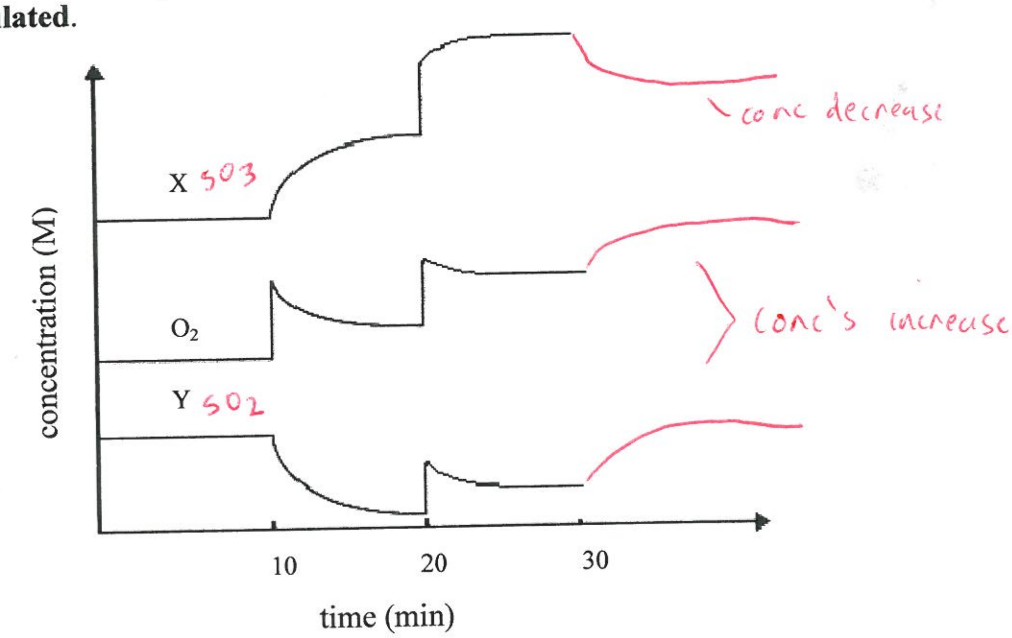
* reaction rate ↑ with ↑ temp despite shift in equilibrium

Question 32.

Part of the Contact Process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation

$$2\,SO_{2(g)} + O_{2(g)} \rightleftarrows 2\,SO_{3(g)} \qquad \Delta H = -192\ \text{kJ mol}^{-1}$$

As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was **initially** at 450°C. The container can change volume and was **thermally well insulated**.



(a) Write the expression for the equilibrium constant for this reaction.

$$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

[1 mark]

(b) Which components of the equilibrium mixture are represented by X and Y?

(i) X: SO_3 [1 mark]

(ii) Y: SO_2 [1 mark]

(c) Suggest what particular changes have been imposed at:

(i) 10 minutes: addition of O_2 to the system [1 mark]

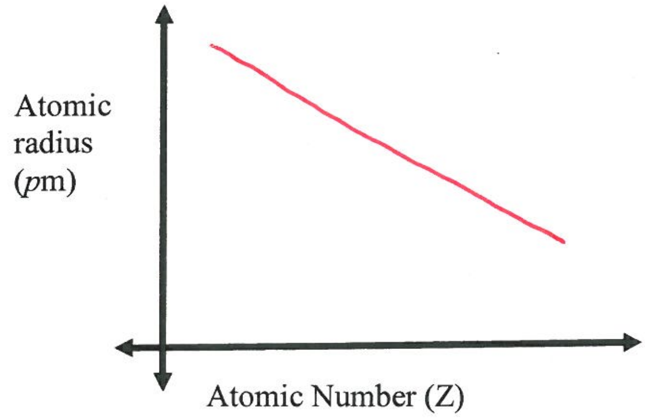
(ii) 20 minutes: decrease in volume of the system [1 mark]

(d) On the graph sketch in the changes if the temperature is increased at time = 30 min. [1 mark]

shift to the left.

Question 33.

Sketch the general graph of the atomic radius of the elements across period 3. Explain the trend illustrated by this graph.



decreases across a period

[1 mark]

• As Z increases across the period the nuclear charge increases (extra protons)
• The additional electron is added to the same outer shell
• The full inner electron shells shield the nuclear charge felt by the outer valence shell and remains constant across the period
• With the increasing nuclear charge and the same shielding by full inner shells the outer shell electrons feel a larger attraction to the nucleus and are pulled in, decreasing the atomic radius.

[4 marks]

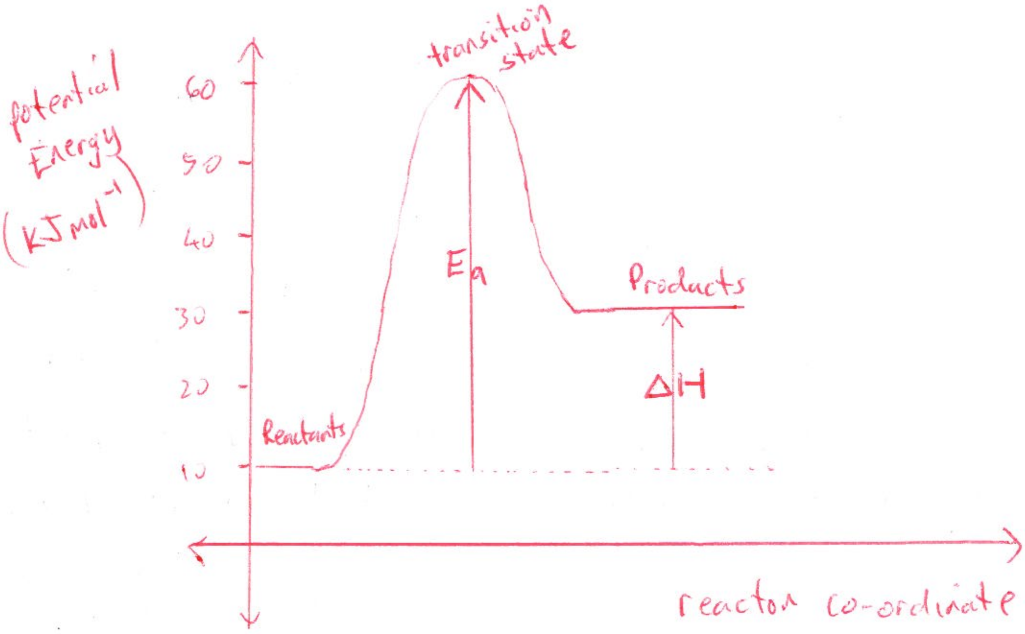
Question 34.

(a) A small increase in the temperature of a reaction will often cause a significant increase in the rate of a reaction. Explain, with reference to collision theory, why this is so. Use diagrams if appropriate.

- For a reaction to take place particles must collide (in orientation) with sufficient energy.
- For a given temperature particles have a variety of kinetic energy.
- The average kinetic energy of particles increases with temperature.
- By increasing the proportion of particles that have sufficient energy the rate of reaction increases. Diagram

[3 marks]

(b) Draw a potential energy diagram for a reaction with $\Delta H = +20$ kJ mol^{-1} and activation energy = 50 kJ mol^{-1}. Label the diagram, including the axes, showing the transition state, products and reactants, along with the activation energy and ΔH.



[3 marks]

* y-axis scale only relative for magnitudes of Ea and ΔH

END OF PART 2

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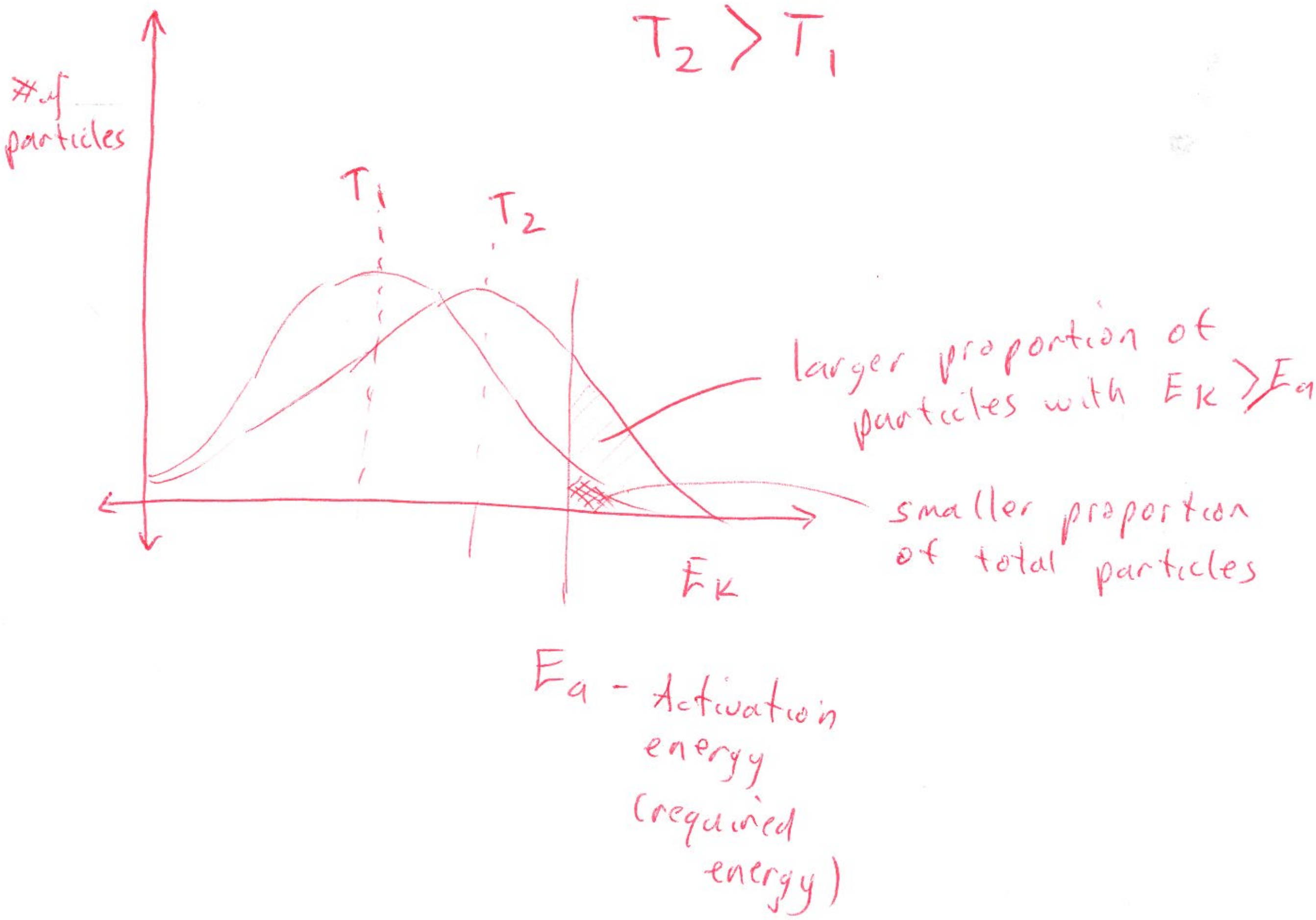


PART 3 **(40 marks)**

Answer **ALL** questions in Part 3. The calculations are to be set out in detail in this Question/Answer Booklet. Marks will be allocated for correct working, correct equations and clear setting out, even if you cannot complete the problem. Note that if an incomplete answer is given only partial marks will be awarded.
When questions are divided into sections, clearly distinguish each section using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet.

Question 35.

Pure metallic nickel can be obtained from crude nickel by reaction with carbon monoxide. This reaction occurs at 50°C and produces nickel carbonyl, $Ni(CO)_4$, which is a gas.

(a) Write an equation for the reaction between nickel and carbon monoxide to produce nickel carbonyl. [2 marks]

(b) What mass of crude nickel will react with 2.76×10^3 L of CO at 103.6 kPa and 50°C if the purity of the nickel is 80.0% [6 marks]

a) $Ni_{(s)} + 4CO_{(g)} \rightarrow Ni(CO)_{4\ (g)}$ balanced (1) states (1)

b) $V(CO) = 2.76 \times 10^3$ L $\quad n(CO) = \frac{PV}{RT}$ (1)

$P = 103.6$ kPa

$T = 50°C$ $\quad = \frac{103.6 \times 2.76 \times 10^3}{8.314 \times 323.15}$

$= 323.15$ K

$R = 8.314$ J K^{-1} mol^{-1}

$= 1.06 \times 10^2$ mol (1)

$n(Ni) = \frac{1}{4} . n(CO)$

$= \frac{1}{4} . 1.06 \times 10^2$

$= \underline{2.66 \times 10^1 \text{ mol}}$ 1

$m(\text{Pure Ni}) = n.M$

$= 2.66 \times 10^1 \times 58.69$ 1

$= \underline{1.56 \times 10^3 g}$

% Ni = 80.0%

$\% Ni = \frac{m(\text{pure Ni})}{m(\text{crude Ni})} \times 100$

$\therefore m(\text{crude Ni}) = \frac{m(\text{pure Ni})}{\% Ni} \times 100$ 1

$= \frac{1.56 \times 10^3}{80.0} \times 100$

$= \underline{1.95 \times 10^3 g}$ 1

(1.95 kg)

Question 36.

The following equation describes the reaction between sulfur tetrafluoride and diiodine pentaoxide:

$$5\ SF_{4\,(g)} + 2\ I_2O_{5\,(s)} \rightarrow 4\ IF_{5\,(l)} + 5\ SO_{2\,(g)}$$

32.07 g of I_2O_5 is shaken with 6.02 L of SF_4 at 76.0°C and 120 kPa, and the reaction allowed to go to completion.

(a) Determine the limiting reagent for this reaction [5 marks]

(b) What volume of sulfur dioxide is produced at 76.0°C and 120 kPa? [2 marks]

(c) What mass of each of the substances (reactants and products) is present at the completion of the reaction? [6 marks]

a) $m(I_2O_5) = 32.07g$

$M(I_2O_5) = 333.8 g mol^{-1}$

$n(I_2O_5) = \frac{m}{M} = \frac{32.07}{333.8} = 9.61 \times 10^{-2} mol$ (1)

$V(SF_4) = 6.02 L$

$T = 76.0°C = 349.15 K$

$P = 120 kPa$

$R = 8.314 J K^{-1} mol^{-1}$

$n(SF_4) = \frac{PV}{RT} = \frac{120 \times 6.02}{8.314 \times 349.15} = 2.49 \times 10^{-1} mol$ (1)

Stoic Ratio $= \frac{n(SF_4)}{n(I_2O_5)} = \frac{5}{2} = 2.50$ (1)

Actual Ratio $= \frac{n(SF_4)}{n(I_2O_5)} = \frac{2.49 \times 10^{-1}}{9.61 \times 10^{-2}} = 2.59$

As A.R. > S.R I_2O_5 is limiting (1)

SF_4 is in excess

Alternatives

$S.R. = \frac{n(I_2O_5)}{n(SF_4)} = \frac{2}{5} = 0.400$

$A.R. = \frac{9.61 \times 10^{-2}}{2.49 \times 10^{-1}} = 0.386$

As A.R. < S.R. I_2O_5 is limiting SF_4 is excess

b) At completion of reaction:

$n(SO_2) = \frac{5}{2} \cdot n(I_2O_5) = \frac{5}{2} \times 9.61 \times 10^{-2}$ (1)

$= 2.40 \times 10^{-1}$ mol

$V(SO_2) = \frac{nRT}{P} = \frac{2.40 \times 10^{-1} \times 8.314 \times 349.15}{120}$

$= 5.81$ L (1)

c) At completion of reaction

$\underset{\text{produced}}{m(SO_2)} = n.M = 2.40 \times 10^{-1} \times 64.06 = 15.4$ g (1)

$n(IF_5) = \frac{4}{2} n(I_2O_5) = \frac{4}{2} \times 9.61 \times 10^{-2}$

$= 1.92 \times 10^{-1}$ mol (1)

$\underset{\text{produced}}{m(IF_5)} = n.M = 1.92 \times 10^{-1} \times 221.9 = 42.6$ g (1)

$\underset{\text{remaining}}{n(SF_4)} = \underset{\text{initial}}{n(SF_4)} - \underset{\text{consumed}}{n(SF_4)}$ (1)

(1) $= 2.49 \times 10^{-1} - \left(\frac{5}{2} \cdot n(I_2O_5)\right)$

$= 2.49 \times 10^{-1} - \left(\frac{5}{2} \times 9.61 \times 10^{-2}\right)$

$= 8.67 \times 10^{-3}$ mol (1)

$\underset{\text{remaining}}{m(SF_4)} = n.M = 8.67 \times 10^{-3} \times 108.06 = 9.37 \times 10^{-1}$ g (1)

Question 37.

The owner of a fresh water swimming pool of volume 31500 L wishes to chlorinate it for the first time using calcium hypochlorite, $Ca(ClO)_2$.

(a) What mass of calcium hypochlorite should be added such that the final concentration of the hypochlorite ion is 15.0 parts per million?
(you may assume that 1 part per million = 1 mg L^{-1})

[4 marks]

(b) The pool owner actually added more calcium hypochlorite than was necessary.

After some days all of the hypochlorite ion had been reduced to chloride according to the equation;

$$2e^- + 2\,H^+_{(aq)} + OCl^-_{(aq)} \rightarrow Cl^-_{(aq)} + H_2O_{(l)}$$

A sample of the pool water was analysed for chloride ion by adding excess silver nitrate and weighing the silver chloride which precipitated. A 200.0 mL sample of pool water produced 0.0362 g of dry silver chloride. What mass of calcium hypochloride did the pool owner actually put into the pool?

[5 marks]

a) $c(ClO^-) = 15\text{ ppm}$
$= 15\text{ mg L}^{-1}$
$= 1.5 \times 10^{-2}\text{ g L}^{-1}$

$m(ClO^-) = c.V$
$= 1.5 \times 10^{-2} \times 31500$
$= 4.73 \times 10^{2}\text{ g}$ (1)

Alternatives:

$n(ClO^-) = \frac{m}{M} = \frac{4.73 \times 10^2}{51.45}$
$= 9.18\text{ mol}$ (1)

$n(Ca(ClO)_2) = \frac{1}{2} \times n(ClO^-)$
$= \frac{1}{2} \times 9.18$
$= 4.59\text{ mol}$ (1)

$m(Ca(ClO)_2) = n.M$
$= 4.59 \times 142.98$
$= 6.57 \times 10^{2}\text{ g}$ (1)
(0.657 kg)

$\%(ClO^-) = \frac{m(ClO^-)}{M(Ca(ClO)_2)} \times 100$
$= \frac{102.9}{142.98} \times 100$
$= 72.0\%$ (1)

$m(Ca(ClO)_2) = \frac{m(ClO^-)}{\%(ClO^-)} \times 100$ (1)
$= \frac{4.73 \times 10^2}{72.0} \times 100$
$= 6.57 \times 10^{2}\text{ g}$ (1)
(0.657 kg)

b) $m(AgCl) = 0.0362 g$ $n(AgCl) = \frac{m}{M} = \frac{0.0362}{143.35}$

$= 2.53 \times 10^{-4} mol$ (1)

$n(Cl^-) = 1 \times n(AgCl) = 2.53 \times 10^{-4} mol$

for 200 mL sample:

$c(Cl^-) = \frac{n}{V} = \frac{2.53 \times 10^{-4}}{0.200} = 1.26 \times 10^{-3} mol\ L^{-1}$ (1)

in 31500 L pool:

$n(Cl^-) = c.V = 1.26 \times 10^{-3} \times 31500$

$= 3.98 \times 10^{1} mol$ (1)

from eqn:

$n(OCl^-) = \frac{1}{1} n(Cl^-) = 3.98 \times 10^{1} mol$

$n(Ca(ClO)_2) = \frac{1}{2} . n(OCl^-) = \frac{1}{2} \times 3.98 \times 10^{1}$

$= 1.99 \times 10^{1} mol$ (1)

$m(Ca(ClO)_2) = n.M = 1.99 \times 10^{1} \times 142.98$

$= 2.84 \times 10^{3} g$ (1)

$(2.84 kg)$

Question 38.

Consider the following table

Substance	Melting Point (°C)	
H_2O	0	covalent - polar - H bonding
O_2	-218	covalent - non-polar - dispersion
Br_2	-7	covalent - non-polar - dispersion
SiO_2	1700	covalent network
NaCl	801	Ionic

Using the above examples discuss in detail the relationship between the melting points and the structures of these solids.
Your answer should describe the process of melting in each case.

Marks are awarded principally for the relevant chemical content of your answer, but some marks can also be gained for clarity in arranging a reasonable amount of material in a coherent form. It is suggested that you write between 1½ and 2 pages to answer the question.

* Responces will vary.

[10 marks]

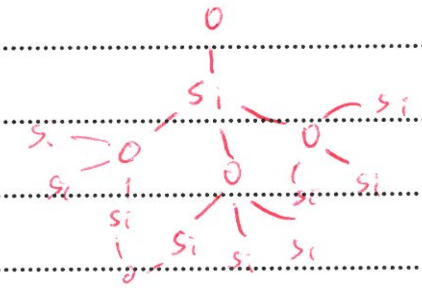
Essay Plan:

- Describe melting at melting point (general)
- Relate M.P. to type of bonding (ionic, covalent, network)
- Relate M.P. to intermolecular forces for covalent. (types and strength)
- Discuss each substance (from lowest to highest M.P.)
  - O_2 - covalent, dispersion only, small # of electrons
  - Br_2 - covalent, dispersion only. larger # of electrons
  - H_2O - covalent, H-bonding (polar)
  - NaCl - ionic - large attraction anion - cation
  - SiO_2 - covalent network - giant structure multiple bonds
- General conclusion - knowing bonding type & structure relate to M.P.

Mr Dhue's essay . . . . .

For a substance to melt, sufficient potential energy must be gained for the particles, in the fixed location of a solid, to move apart and slide past eachother as a liquid. This potential energy can vary depending on bonding type and strength of intermolecular forces.

In general Covalent network has very high melting points due to the giant lattice structure where there are many bonds holding the solid together. These bond require large amounts of energy to break giving these substances their high melting point. eg. SiO_2 m.p. = 1700°C

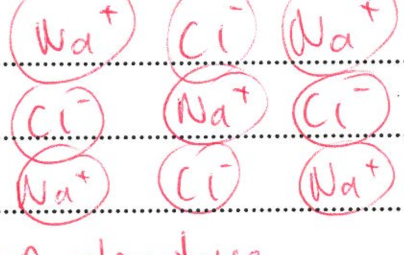


3-D structure

many bonds locking the ordered structure..
Despite being covalent the multiple numbers of the bonds give rise to very high melting points

Ionic substances also have a high melting point due to the strong electrostatic between the Anions and Cations. These attractions must be broken for the ionic substance to become a liquid.

eg NaCl mp = 801°C



3.D. structure

Ions in fixed positions as a solid, needs large amount of energy to move apart and become liquid.

For covalent molecular substances, the melting point depends on the strength of the intermolecular forces holding the molecules together as a solid. The greater the strength the higher the melting point.

As a general rule dispersion forces give the weakest intermolecular forces. Dispersion forces are temporary dipoles due to momentary oscillations of electron charge. Dispersion forces increase with more electrons (as probability and charge magnitude increase)

(also called London forces)

eg O_2 M.P = −218°C

dispersion force

O=O ····· O=O

weak intermolecular force low M.P.

Br_2 M.P. = −7°C

dispersion force

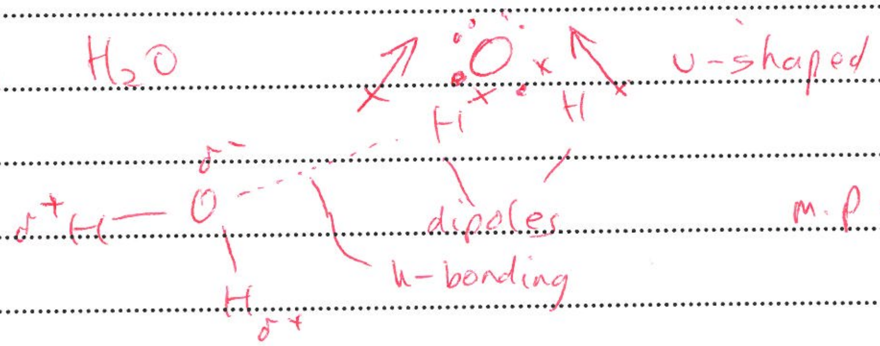
Br−Br ····· Br−Br

more electrons than O_2 so larger dispersion forces but still a low melting point.

Other intermolecular forces include dipole-dipole and hydrogen bonding. If the bond polarities and molecule shape allow a formation of a dipole these charged regions can attract eachother. This gives a stronger intermolecular force than dispersion forces.

Hydrogen bonding is a special type of dipole-dipole due to the large electronegativity difference of O, F and N when bonded to H. This causes a large dipole which gives a stronger intermolecular force than dipole-dipole.

eg H_2O



m.p = 0°C

The melting point of substances is directly related to the type of bonding and the strength of the intermolecular forces and can be used to determine the nature of substances.

END OF EXAM