Applecross Senior High School

AECHE 2017
Covalent Molecules and Gases
Test

Time allowed: 55 minutes

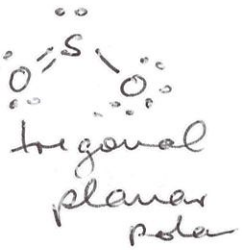
Name: Marking Key.

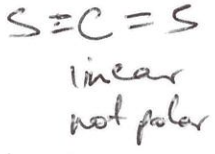
Section	Raw Marks	Mark Scored
Part A	/15	/27
Part B	/40	/73
Total	/55	/100 = %

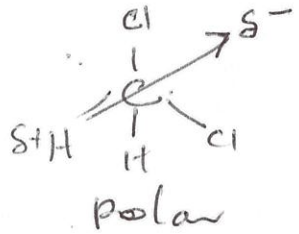
Part A: Multiple Choice Questions [15 marks]

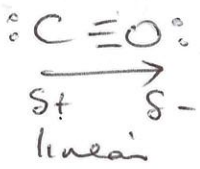
1. Which of the following would have dispersion forces as the **only** intermolecular force present in a pure sample?

(a) SO_2 polar
(b) CS_2 non polar
(c) CH_2Cl_2 polar
(d) CO polar

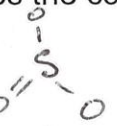




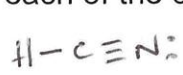




2. Which of these gives the correct shape for each of the covalent molecules?



	SO_3	HCN	F_2O
(a)	pyramidal ✗	linear ✓	bent / v-shaped ✓
(b)	trigonal planar ✓	linear ✓	bent / v-shaped ✓
(c)	trigonal planar ✓	bent / v-shaped ✗	linear ✗
(d)	pyramidal ✗	trigonal planar ✗	linear ✗



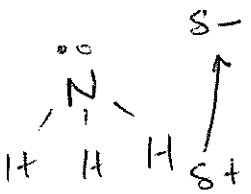
3. As water evaporates from an **open** container at 40°C, which one of the following is **true**?

(a) The water becomes ~~warmer~~ ✗ as the kinetic energy of the liquid water molecules increases.
(b) The water molecules decompose into hydrogen and oxygen molecules. ✗
(c) The water has a constant temperature as molecules return to the surface as fast as they leave it. ✗
(d) The water becomes cooler as the kinetic energy of the liquid water molecules decreases. ✓

4. Hot-air ballooning involves heating the air in a large overhead balloon. Which one of the following statements best explains why the balloon rises as the air is heated?

(a) Heating air decreases the volume it occupies.
(b) Atmospheric pressure decreases with temperature.
(c) The air in the balloon becomes less dense as it is heated.
(d) The pressure in the balloon decreases as it is heated.

5. The boiling points of the first three Group 15 hydrides are shown in the table below.



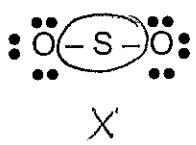
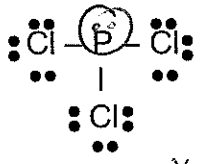
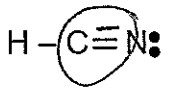
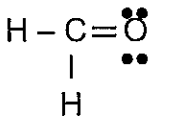
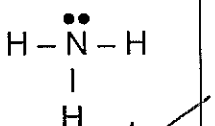
	Boiling point (°C)
NH_3	-33
PH_3	-88
AsH_3	-63

Which of the following statements are correct?

(i) NH_3 has the strongest dispersion forces
(ii) All the molecules have dipole-dipole forces
(iii) NH_3 has the strongest intermolecular forces
(iv) NH_3 is the only molecule to have hydrogen bonding
(v) AsH_3 is the most polar molecule

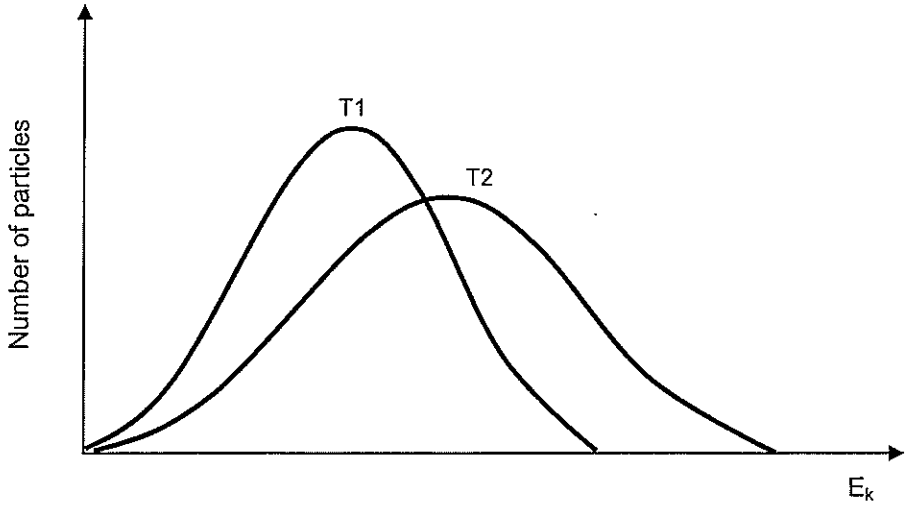
(a) (ii) and (iv) only
(b) (i), (ii) and (iv) only
(c) (i), (iii) and (iv) only
(d) (ii), (iii) and (iv) only

6. Which of the following structural / electron dot diagrams are correct?

(i)	(ii)	(iii)	(iv)	(v)
SO_2	PCl_3	HCN	CH_2O	NH_3
				

(a) (iv) and (v) only
(b) (i), (ii) and (v) only
(c) (i) and (v) only
(d) (ii), (iv) and (v) only

7. The following graph shows the kinetic energy distribution of a reacting system at two different temperatures.



Which of the following statements are correct?

(i) At T1 the particles have a lower average kinetic energy ✓
(ii) T1 represents a lower temperature ✓
(iii) At T2 the particles have a higher average kinetic energy ✓
(iv) At T2 there are a greater number of particles present ✗

(a) (i) and (iii) only
(b) (i), (ii) and (iii) only
(c) (ii) and (iv) only
(d) (i) and (iv) only

8. In which of the following are the covalent bonds ranked in order of decreasing polarity (i.e. most polar to least polar)?

electronegativity
F > O > Br > C

(a) H-O > H-F > H-Br > H-C
(b) H-C > H-Br > H-O > H-F
(c) H-F > H-C > H-O > H-Br
(d) H-F > H-O > H-Br > H-C

9. Which of the following statements regarding gas pressure is **not** correct for a given mass of gas?

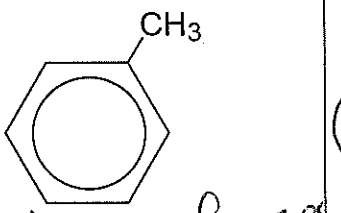
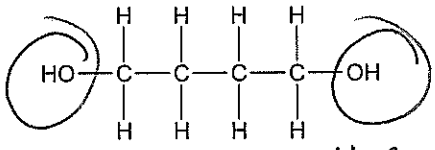
(a) At constant temperature, a decrease in the volume of a gas will increase the pressure ✓
(b) Pressure is determined by the number of collisions the gas particles have with the walls of the container ✓
(c) At constant volume, an increase in the temperature of a gas will decrease ✗ the pressure
(d) The volume and pressure of a gas are inversely proportional ✓

10. What physical property of water does the paragraph below describe?

"Water molecules are strongly attracted to each other through cohesive forces. In liquid water, most molecules are attracted to neighbouring water molecules above, below and on all sides. However, the molecules at the surface of the liquid do not have water molecules above them and are therefore pulled more strongly downwards by the water molecules below them."

(a) Surface tension ✓
(b) Hydrogen bonding
(c) Vapour pressure ✗
(d) Density ✗

11. Consider the information given in the following table.

	Toluene	Butane-1,4-diol
Structural diagram	 dispersion forces	 H Bonding ↑ IMF → ↑ V_p.
Molar mass, M ($g\ mol^{-1}$)	92.134	90.12
Vapour pressure at 50 °C (kPa)	12.28 large P	0.014 Small P.

Which is the **best** explanation for the difference in vapour pressure of these two compounds?

(a) Toluene has a higher molar mass than butane-1,4-diol
(b) Butane-1,4-diol has fewer carbon atoms in its structure than toluene
(c) Toluene has stronger dispersion forces than butane-1,4,-diol
(d) Butane-1,4-diol has stronger intermolecular forces than toluene

12. If the volume of a constant mass of gas is halved at constant temperature, which of the following are **true**?

(i) the pressure of the gas would increase ✓
(ii) the average kinetic energy of the gas would increase ✗
(iii) the number of collisions between the gas particles would increase ✓

(a) (i) only
(b) (i) and (iii) only
(c) (iii) only
(d) (i) and (ii) and (iii)

13. What change(s) occur(s) while a liquid is boiling?

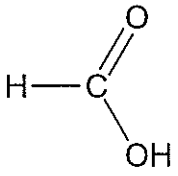
(i) The average kinetic energy of the particles increases.
(ii) The attractive forces between the particles become stronger.
(iii) The spacing between the particles increases.

(a) (i) only
(b) (ii) and (iii) only
(c) (iii) only
(d) (i) and (iii) only

14. Two identical flasks are both at 0°C and 100 kPa pressure. One flask contains carbon dioxide gas (CO_2) and the other flask contains nitrogen gas (N_2). Which one of the following statements about the gases in the two flasks is true?

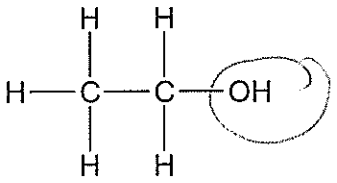
(a) The average kinetic energy of the CO_2 particles is greater than that of the N_2 particles.
(b) The average velocity of the particles in the two flasks is the same.
(c) The flasks contain the same mass of gas.
(d) The average kinetic energy of the particles in the two flasks is the same.

15. Formic acid (methanoic acid) is used as a preservative and antibacterial agent, as well as in various cleaning products. It has a boiling point of 101 °C and its structure is shown to the below.

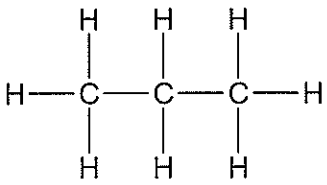


Which of the following substances would be **least** soluble in formic acid?

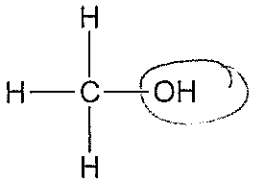
(a)



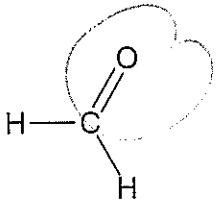
(b)



(c)



(d)



Part B: Extended Answer Questions [40 marks]

Show all working and express your answer in scientific notation with the correct number of significant figures for full marks.

Question 16 **(5 marks)**

When 4.22 g (3 sf) of solid zinc metal is mixed with excess hydrochloric acid, a gas is produced according to the following equation:

$$Zn_{(s)} + 2H^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_{2(g)}$$

1 mol + 2 mol → 1 mol + 1 mol

(a) How many moles of hydrogen gas will be produced? (3 marks)

$n_{Zn} = \frac{m}{M}$

$= \frac{4.22}{65.38}$ (1)

$= 6.454 \times 10^{-2}$ mol (1)

$n_{H_2} = n_{Zn} = 6.45 \times 10^{-2}$ mol. (1).

(b) What volume will this hydrogen gas occupy at S.T.P.? (2 marks)

$n = \frac{V}{22.71}$

$V_{H_2} = n \times 22.71$ (1)

$= 6.45 \times 10^{-2} \times 22.71$

$= 1.47$ L (1)

Question 17 **(8 marks)**

Dry ice is the name given to solid carbon dioxide (CO_2). It is often used in theatre productions, because at room temperature dry ice will 'sublime' or turn from the solid state directly into a gas. This creates white 'clouds' that can be used for various special effects.

(a) A small piece of dry ice was placed in a sealed metal container at room temperature. Explain, in terms of the kinetic theory, why the pressure inside the container would have changed once the piece of dry ice has sublimed and the container had returned to room temperature. (3 marks)

- At room temperature $CO_2(s) \rightarrow CO_2(g) \rightarrow \uparrow n_{CO_2}$. (1)
- ↑ collisions of CO_2 molecules with walls of container (1)
- ↑ collisions → ↑ pressure (1).

(+½ mark for ↑ E_K → ↑ collisions → ↑P)

Under conditions of high pressure and/or low temperature, gases will not behave as 'ideal gases'.

(b) State one example of how gases vary from the expected behaviour of ideal gases. Explain why this variation occurs. (2 marks)

Real gases —

- at low P & T gas condense to form liquid.

or

- ≠ 22.71 L at STP due to attractive forces

* any reasonable example (1) + explanation (1).

(c) A 3.75 L cylinder was storing 5.28 g of a gas at STP. Could the identity of this gas be carbon dioxide? Explain, showing all working. (3 marks)

$n = \frac{V}{22.71}$

$= \frac{3.75}{22.71}$

$= 1.651 \times 10^{-1}$ mol

$n = \frac{m}{M}$

$M_x = \frac{m}{n}$

$= \frac{5.28}{1.651 \times 10^{-1}}$

$= 32$.

$M_{CO_2} = 12.01 + (2 \times 16)$

$= 44.01$

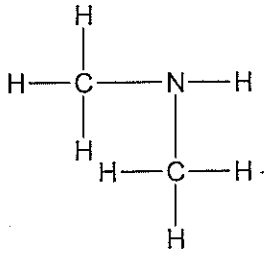
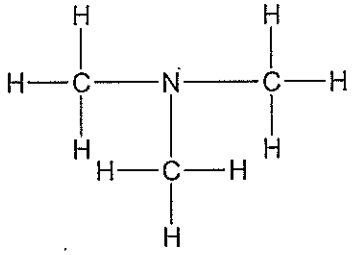
since $M_x \neq M_{CO_2}$

$32 \neq 44.1$

the gas is not CO_2.

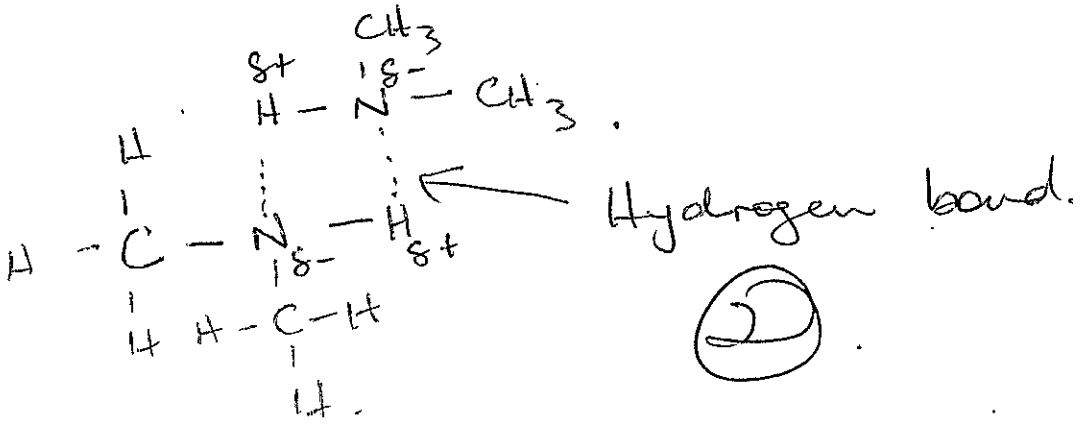
Question 18 **(7 marks)**

Consider the information given in the table below.

Dimethylamine	Trimethylamine
	
Boiling point 8 °C	Boiling point -3 °C

(a) Dimethylamine has the ability to form hydrogen bonds. Explain in detail how hydrogen bonds form and draw a diagram showing these bonds in dimethylamine. (4 marks)

Hydrogen bonds form between the nitrogen atom of one molecule and the Hydrogen attached to the nitrogen of another molecule. (2)



(2)

(b) Explain why trimethylamine has the stronger dispersion forces, but dimethylamine has the higher boiling point. (3 marks)

Trimethylamine has more electrons which form more instantaneous dipoles → ↑ dispersion forces. (1)
only dimethylamine has H-Bonds (1)
= stronger intermolecular force and requires more energy to separate molecules (1).

Question 19 **(8 marks)**

When scientists are looking for other planets that might support life, they search for those that may have liquid water. Water is one of the main reasons that life can exist on planet Earth.

One of the special properties of water is that its solid form (ice) is less dense than its liquid form.

(a) Explain this property in terms of the structure and bonding present in water, and give an example of how this property of water is essential to the survival of many aquatic life forms found on Earth. (4 marks)

- Hydrogen bonding in ice (1)
- water molecules orientate to form more hydrogen bonds (1)
- the ice lattice has more space between molecules → ↓ density and ∴ floats on liquid water (1)
- Lakes freeze from top down to allow aquatic animals to survive winter (1)

(b) Complete this table by drawing the structural formula for each of the three gases, representing all valence shell electron pairs either as : or –. In addition, state the shape of the molecule, and indicate whether or not the molecule contains polar bonds or is a polar molecule. (6 marks)

	Structural diagram	**Shape**	**Polar bonds ('yes' or 'no')**	**Polar molecule ('yes' or 'no')**
N_2	:N:::N:	linear	no	no
CO_2	:O::C::O:	linear	yes	no
H_2O	H–O–H	bent / V-shape	yes	yes.

½ each.

Question 20 **(5 marks)**

A 2.80 L sample of a gaseous organic compound at S.T.P. is found to have a mass of 7.00 g.

(a) Calculate the molar mass of the compound. (3 marks)

3 sf.

3 sf.

$n_{gas} = \frac{V}{22.71}$

$= \frac{2.80}{22.71}$ (1)

$= 0.1233$ moles. (1)

$M_{gas} = \frac{m}{n}$

$= \frac{7.00}{0.1233}$

$= 5.68 \times 10^{1}\ g\,mol^{-1}$ (1)

(b) Determine the molecular formula of the compound if its general formula is known to be CnH2n. (2 marks)

$M_{C_nH_{2n}} = 12.01 + (2 \times 1.008)$

$= 14.026$

$\frac{M_{gas}}{M_{C_nH_{2n}}} = \frac{56.8}{14.026}$ (1)

$= 4.05$

≈ 4.

$\therefore M_{gas} = C_4H_8$ (1)

Question 21 **(7 marks)**

Hydrogen gas may also be used as a fuel, and reacts with oxygen when ignited to form water according to the reaction below.

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O(\ell)$$

2 mol + 1 mol → 2 mol.

(a) Calculate the density of hydrogen gas at STP. (2 marks)

1 mol H_2 gas at STP = 22.71 L

$m_{H_2} = 2 \times 1.008 = 2.016$ g. (1)

$$\text{Density}(\rho) = \frac{m}{V}$$

$$= \frac{2.016}{22.71}$$

$= 8.88 \times 10^{-2}$ g L^{-1}. (1)

2 sf.

(b) If 1200 kg of hydrogen gas is ignited in air to form H_2O. What volume of oxygen gas will react with this mass of hydrogen at S.T.P.? Your answer must be expressed with the appropriate number of significant figures and must include units. (4 marks)

$1200 \text{ kg} \times 1000 = 1.2 \times 10^6$ g.

$n_{H_2} = \frac{1.2 \times 10^6}{2.016} = 5.95 \times 10^5$ mol. (1)

$n_{O_2} = \frac{1}{2} n_{H_2} = \frac{1}{2} \times 5.95 \times 10^5$

$= 2.98 \times 10^5$ mol. (1)

$V_{O_2} = 22.71 \times n_{O_2}$

$= 22.71 \times 2.98 \times 10^5$

$= 6.8 \times 10^6$ L. (1)

(b) Given that air is approximately 20% oxygen by volume, what volume of air would be required to react with 1200 kg of hydrogen gas? (1 mark)

$\frac{6.8 \times 10^6 \times 100}{20} = 3.4 \times 10^7$ L. (1)