205
F15
Rogers
answer key.

Examination Cover Sheet

COURSE: Chem	**NUMBER:** 205	**SECTION(S):** 02	
EXAMINATION: _✓_ **FINAL** ___ **ALTERNATE** ___ **DEFERRED** **VERSION:** _____	**DATE:** Dec. 14th, 2015	**TIME:** 7-10 pm	**PAGES: 7** **Including cover** **DOUBLE-SIDED** **= 14 pages**
INSTRUCTOR(S): C. Rogers		**DIVISION:**	
MATERIALS ALLOWED: _No!_ Booklets _✓__ IBM (Scantron) _✓_ Blue **or** ___ Green _✓__ Printed Translation Dictionary Other__NO_____ _✓__ Calculator ___ENCS Approved ____ Other ____No_____		**INSTRUCTIONS:** _✓_ Return all _✓_ Answer on Exam _No_ Open book _No__ Crib sheet Details_____	

Please print your name and I.D. number in the spaces below.

LAST NAME: _____

FIRST NAME: _____

STUDENT I.D. # _____

SPECIAL INSTRUCTIONS:

- Part I: Use the question pages for rough work; only the Scantron sheet will be graded.
- Parts II-III: Write your answers in the spaces provided (p.9-10). If you need extra space, use the blank pages (p.11-12). Please clearly indicate if those pages should be graded.
- Potentially useful information and a periodic table are on p.13-14.

Please leave this area blank:	Mark breakdown (professor use):	
	Part I:	/ 76
	Part II:	/ 10
	Part III:	/ 14
	TOTAL:	**/ 100**

answer key

Part I – MCQs: The following 38 questions are multiple choice questions worth 2 marks each. There is ONE correct choice per question. You can do rough work on the exam paper, but it will not be marked. Enter your name, student ID number and MCQ answers on the Scantron sheet, in PENCIL. *(Circles must be coloured in completely. Your birth date and other details are not needed.)*

1. All atoms of the same element have the same number of _____ in their nucleus. What is the missing word or words?

C
a. neutrons
b. electrons
85% (c) protons
d. neutrons and protons
e. neutrons, protons, and electrons

2. What method is used to determine the exact masses of isotopes and their relative abundances?

E
a. density measurements
b. filtration
c. electron microscopy
d. titration
89% (e) mass spectrometry

3. Which pair of atoms has the same number of neutrons?

E
a. $^{28}_{12}Mg$ and $^{28}_{11}Na$ 16 & 17
b. $^{26}_{12}Mg$ and $^{28}_{12}Mg$ 14 & 16
c. $^{28}_{14}Si$ and $^{28}_{12}Mg$ 14 & 16
d. $^{28}_{14}Si$ and $^{28}_{11}Na$ 14 & 17
88% (e) $^{28}_{14}Si$ and $^{26}_{12}Mg$ 14 & 14

4. What are the values for x and y for $Al_x(CO_3)_y$?

B
a. x = 1 and y = 2
73% (b) x = 2 and y = 3
c. x = 1 and y = 3
d. x = 3 and y = 1
e. x = 3 and y = 2

$Al^{3+} : CO_3^{2-}$

$Al_2(CO_3)_3$

x y

5. The density of carbon tetrachloride is 1.59 g/mL. What is the mass of 50.00 mL of CCl_4?

C
a. 0.0318 g
b. 79.50 g
74% (c) 79.5 g
d. 31.45 g
e. 31.4 g

$d = \frac{m}{V}$

$m = d \times V$

$= \left(1.59 \frac{g}{mL}\right)(50.00\ mL)$

$= 79.50\ g$

$\doteq 79.5\ g$

answer key

6. Methane reacts with oxygen to form carbon dioxide and water.

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$$

Which one statement concerning this reaction is INCORRECT ?

a. T two moles of water are formed for one mole of methane consumed.
b. T two molecules of oxygen are consumed per one molecule of methane consumed.
D c. T the combined mass of reactants consumed equals the mass of products formed.
86% (d) two grams of oxygen are consumed for each gram of carbon dioxide formed.
e. T three moles of gases are formed for each three moles of gases consumed.

7. What is the formula of chromium (III) oxide?

78% (a) Cr_2O_3 $2Cr^{3+} : 3O^{2-}$
A b. Cr_3O_2
c. CrO_3
d. Cr_3O
e. Cr_3O_3

8. What is the net ionic equation for the reaction of KOH and HCl in aqueous solution?

a. $H^+(aq) + KOH(aq) \rightarrow H_2O(\ell) + K^+(aq)$ $K^+ + OH^- + H^+ + Cl^- \rightarrow H_2O + K^+ + Cl^-$
25% b. $K^+(aq) + Cl^-(aq) \rightarrow KCl(aq)$
D c. $HCl(aq) + KOH(aq) \rightarrow H_2O(\ell)$
69% (d) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
e. $KOH(aq) + H_2O(\ell) \rightarrow H^+(aq) + K(OH)_2(s)$

9. You measure water in two containers: a 10-mL graduated cylinder with marks at every mL, and a 1-mL pipet marked at every 0.1 mL. If you add the two measured volumes together in a calculation in your notebook, to what decimal place should you express the total?

a. 0.001 mL e.g. 15.5 mL in 10mL/1mL cylinder
C b. 0.01 mL 0.55 mL in 1mL/0.1mL pipet
44% (c) 0.1 mL 6.05 mL
31% d. 1 mL ↑ limited here
e. 10 mL

10. Which of the following is NOT a physical change? i.e. which is a CHEMICAL change?

a. freezing a liquid to form a solid phys.
D b. dissolving a solid in water to form a solution phys.
c. evaporating liquid water to form steam phys.
98% (d) burning a piece of paper to form gases and smoke chem.
e. sublimating a piece of ice to form water vapour phys.

11. What is the pH and description of a dilute HCl solution with a concentration of 0.030 M?

a. ✗ pH 12.48, acidic solution acidic
b. ✗ pH 12.48, basic solution pH < 7
D c. ✗ pH 7.00, neutral solution no calculation required!
83% (d) pH 1.52, acidic solution
e. ✗ pH 1.52, basic solution

12. What is the energy of a single photon of γ-radiation with a wavelength of 1.33×10^{-12} m?

a. 9.34×10^{-18} J
b. 4.41×10^{-15} J
C 83% (c) 1.49×10^{-13} J
d. 8.34×10^{-12} J
e. 2.10×10^{-11} J

$E = h\nu = \frac{hc}{\lambda}$

$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ J \cdot s)(2.9979 \times 10^{8}\ m \cdot s^{-1})}{1.33 \times 10^{-12}\ m}$

$\therefore E = 1.49 \times 10^{-13}\ J$

13. What type of orbital is designated by $n = 2, \ell = 0, m_\ell = 0$?

78% (a.) 2*s*
b. 2*p*
A c. 2*d*
d. 2*f*
e. None

2nd E level; s

14. Which of the following is associated with the value of the (m_ℓ) quantum number?

48% (a.) orbital orientation
b. ✗ number of nodes
2 for A 38% c. angular momentum quantum number
d. ✗ orbital size
1 for C e. ✗ de Broglie wavelength

Since m_ℓ depends on ℓ value...

m_ℓ from $-\ell \rightarrow 0 \rightarrow +\ell$ in integral units, represents # orbitals in subshell, each with unique orientation

ℓ, shape (subshell)

n, energy level

15. How many electrons can be described by the quantum numbers $n = 4, \ell = 2, m_s = +½$?

17% a. 1
b. 2
D c. 3
59% (d.) 5
e. 10

4d

all one particular spin orientation ("up")

no m_ℓ specified, so refers to every orbital in d subshell

{ 1 1 1 1 1

16. What is the density of carbon dioxide gas at standard temperature and pressure (STP)? 0°C, 1 atm P

g/L

a. 0.89 g/L
b. 1.00 g/L
E 18% c. 1.32 g/L
d. 1.68 g/L
51% (e.) 1.96 g/L

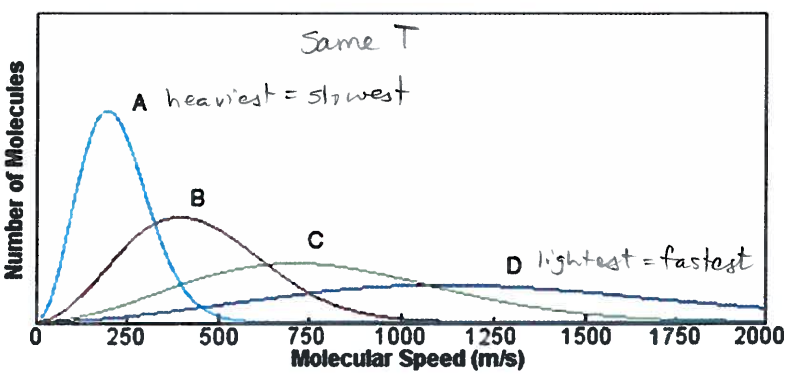
at STP, 1 mol of gas = 22.42 L

1 mol of CO_2 = 44.008 g

$\therefore d = \frac{44.008\ g}{22.42\ L} = 1.96\ \frac{g}{L}$

17. The Boltzmann plot shown reveals the distribution of molecular speeds for 4 gases at the same temperature. Which choice is the most likely list of gases A, B, C, D to produce the curves shown on this graph?

A 57% (a.) Xe, O_2, Ne, He
b. Xe, He, Ne, O_2
24% c. ✗ He, Ne, O_2, Xe
d. ✗ He, O_2, Ne, Xe



18. Which type of elements have *least* affinity for electrons?

a. transition metals
32% b. main group metals
59% c. noble gases
d. main group nonmetals
e. semiconductors

C

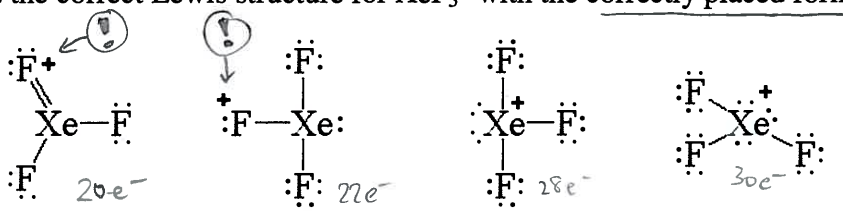
19. Which of the following elements is most likely to NOT obey the octet rule in a molecule?

83% a. B
b. C
c. N
d. O
e. F

A

20. What is the correct Lewis structure for XeF_3^+ with the correctly placed formal charge?

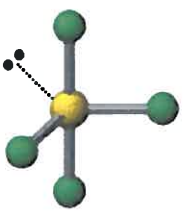
XeF_3^+
$8+3(7)-1 = 28e^-$



a. X b. X c. 81% d.

C

21. A ball-and-stick structure of AsF_4^- is shown on the right. How is the *electron-pair* (basic) geometry described?



a. pentagonal
b. seesaw
72% c. trigonal bipyramidal
d. tetrahedral
e. square planar

C

22. How is the *molecular* geometry of AsF_4^- (see figure in Q.21) described?

a. pentagonal
72% b. see-saw
c. trigonal bipyramidal
d. tetrahedral
e. square planar

B

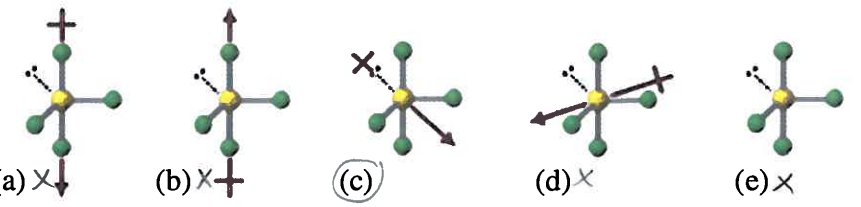
23. In AsF_4^- (see figure in Q.21), the lone pair is observed to be in an equatorial site, not axial. Why is this geometry favoured?

a. T Arsenic atoms are bigger than fluorine. True but not relevant.
23% b. T Arsenic is less electronegative than fluorine. True but not relevant.
69% c. T The bulky lone pair makes fewest 90° contacts with neighbouring As–F bond-pairs.
d. F Lone pairs prefer to have as many neighbours as possible, no matter what the angle.
e. F The lone pair prefers the warmer temperatures near the equator.

C

24. SF_4 is isoelectronic and isostructural with AsF_4^-. How is it polarized (see figures below)?

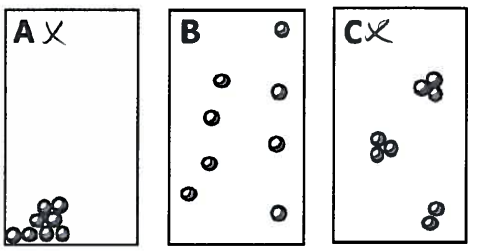
$\chi_S < \chi_F$



C

a. It is polarized with the net dipole along the axial direction, positive at the top.
b. It is polarized with the net dipole along the axial direction, positive at the bottom.
63% (c) It is polarized with the net dipole aligned with the S – lone-pair axis.
d. It is polarized with the net dipole perpendicular to the S – lone-pair axis.
e. It is not polarized.

25. Which of the images would best describe helium gas?



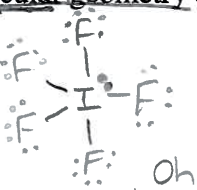
B

a. A
89% (b) B
c. C
d. all
e. none

26. According to VSEPR theory, what is the molecular geometry of IF_5?

D

a. tetrahedral
b. trigonal bipyramidal
18% c. see-saw
64% (d) square pyramidal
e. octahedral



$7+5(7)+0 = 42e^-$

$8 \times 5 = 40$
$\therefore$ 2 more e^- on I

Oh & 1 lone pair = Square pyramidal
basic

27. What is the hybridization of the central ~~nitrogen~~ iodine in IF_5?

Oh = 6 pairs = sp^3d^2

E

a. *sp*
b. sp^2
c. sp^3
28% d. sp^3d
61% (e) sp^3d^2

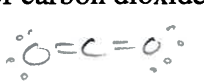
28. What is the number of sigma (σ) bonds and pi (π) bonds in a molecule of carbon dioxide?

C

a. 4 σ and 0 π
b. 3 σ and 1 π
82% (c) 2 σ and 2 π
d. 1 σ and 3 π
e. 0 σ and 4 π

$\frac{1}{1} + \frac{1}{1} \Rightarrow$ double bonds

$\frac{1}{2} \quad \frac{1}{2}$



29. You are given temperature readings for two locations on Earth: 29 °C and 256 K. Which choice correctly ranks these temperatures?

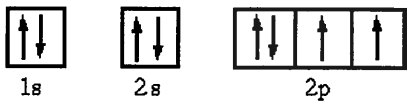
+273
302 K

A

97% (a) 29 °C is warmer than 256 K
b. 29 °C is the same as 256 K
c. 29 °C is colder than 256 K

answer key

30. Which element has the following electron configuration?



$1s^2 2s^2 2p^4$ = oxygen.

a. P
b. S
C 94%. c. O
d. N
e. F

31. Which of the following chemical equations refers to the second ionization of Ca? ionization E measured in gas phase always...

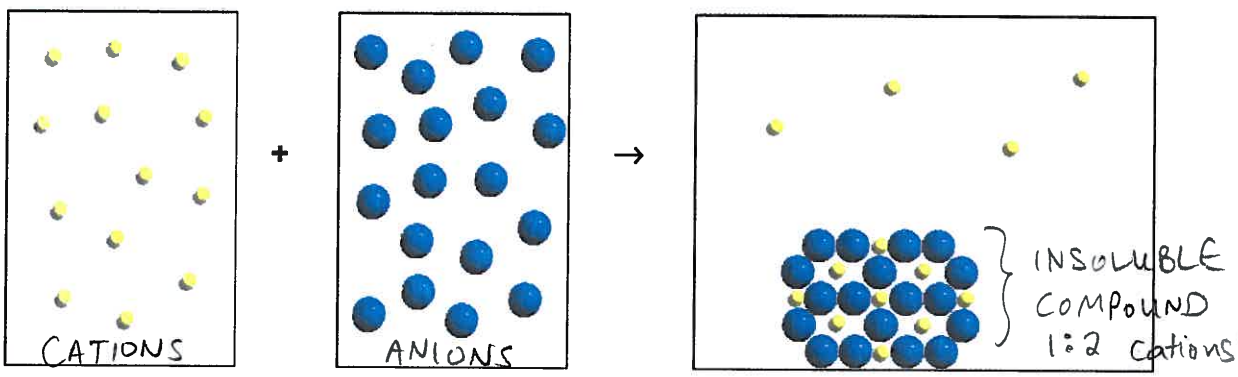
a. ×Ca(s) + 2e⁻ → Ca^{2-}(s)
25% b. ×Ca(g) → Ca^{2+}(g) + 2e
E c. Ca^{2+}(g) → Ca^{+}(g) + e^-
d. Ca(s) → Ca^{+}(s) + e^-
44% e. Ca^{+}(g) → Ca^{2+}(g) + e^-

1st: $Ca_{(g)} \rightarrow Ca^{+}_{(g)} + 1e^-$
✱2nd: $Ca^{+}_{(g)} \rightarrow Ca^{2+}_{(g)} + 1e^-$

32. Which of the following statements about electrons and atoms is INCORRECT?

a. T Nearly all of the mass of an atom is localized in its central core or nucleus.
18% b. T Electrons are best described as standing waves oscillating in the space around the nucleus.
C 66% c. F Electrons circle the nucleus in elliptical orbits determined by the atom's nuclear charge.
d. T In addition to being farthest from the nucleus, the electrons in the valence shell are also responsible for an element's chemical properties.
e. T When an atom absorbs an ultraviolet photon, an electron moves to a higher energy level.

33. An aqueous solution containing cations (shown as smaller light spheres in left box) is mixed with a solution containing polyatomic anions (simplified as larger dark spheres in right box), in the quantities shown. The diagram on the right illustrates the result obtained.
(Note: Water molecules and spectator counter-ions not shown.)



Which combinations of cation and anion from the lists below are compatible with the observed results? **Possible cations:** K^+, Ni^{2+}, NH_4^+, Mg^{2+} **& Anions:** OH^-, NO_3^-, ClO_4^-, SO_4^{2-}

always soluble

a. KOH, $Ni(NO_3)_2$, NH_4ClO_4, $MgSO_4$
b. $Ni(OH)_2$, $NiSO_4$, $Ba(OH)_2$, $MgSO_4$ = all insoluble
E c. KOH, KNO_3, NH_4NO_3, NH_4ClO_4
d. $(NH_4)_2SO_4$, K_2SO_4
e. $Ni(OH)_2$, $Mg(OH)_2$ = all insoluble AND right ion ratio (1:2 cations:anions)

THE REMAINING MULTIPLE-CHOICE QUESTIONS DEAL WITH THIS SCENARIO:

Sulphuric acid is listed in a catalog as having a concentration of 95-98% H_2SO_4 by weight. The label on a bottle in the stockroom shows the density as 1.85 g/mL. In order to determine the actual concentration of acid in the bottle, a student dilutes 5.00 mL of the concentrated acid to 500. mL. She then takes four 10.00 mL samples and titrates each sample with standardized 0.1790 M sodium hydroxide solution. The results (in order) were:

Sample "run"	1st	2nd	3rd	4th
Volume NaOH (mL)	~20.70	20.30	20.40	20.35

H_2SO_4 MM = 98.082 g/mol avg: 20.35 (0.05, 0.05, 0) ⇒ avg dev = 0.03

34. Based on the advertised 95-98% by weight composition listed in the catalog and the density of 1.85 g/mL, what is the *expected* molarity range of the *concentrated* sulphuric acid solution?

B
- a. ✗ 36 – 37 mol/L
- 50% b. 18 – 19 mol/L
- c. 17 – 20 mol/L
- d. ✗ 3.6 – 3.7 mol/L
- 19% e. ✗ 1.7 – 1.9 mol/L

min $\frac{95}{100} \times \frac{1.85\,g}{1\,mL} \times \frac{1000\,mL}{1\,L} \times \frac{1\,mol}{98.0828} = 17.92 \frac{mol}{L} \approx 18$

max $\frac{98}{100} \times \ldots = 18.48 \frac{mol}{L} \approx 18.5$

35. Would you consider the titration results to be relatively precise? Why or why not?

C
- a. Not precise – the average deviation of the volumes from runs 2-4 was > 5%.
- b. ✗ Not precise – the relative error of the volumes from runs 2-4 was > 5%.
- 51% c. Precise – the average deviation of the volumes from runs 2-4 was < 5%.
- d. ✗ Precise – the relative error of the volumes from runs 2-4 was < 5%.
- 19% e. More than one of these answers is correct. no way to judge relative error?

36. What type of reaction is involved in this titration? $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(l)} + Na_2SO_{4(aq)}$

C
- a. ✗ precipitation
- b. gas-forming
- 67% c. acid-base
- d. ✗ redox
- 22% e. both b & c

37. How many moles of sulphuric acid were consumed on average in titration runs 2-4?

C
- a. 7.285×10^{-3} mol
- 45% b. 3.643×10^{-3} mol
- 34% c. 1.821×10^{-3} mol
- d. 5.685×10^{-2} mol
- e. 1.137×10^{-1} mol

$V_{NaOH} = 20.35$ mL $c = \frac{n}{V} \therefore n_{NaOH} = (0.02035\,L)(0.1790\,\frac{mol}{L}) = 3.642 \times 10^{-3}$ mol

1 H_2SO_4 per 2 NaOH $\therefore n = 1.821 \times 10^{-3}$ mol H_2SO_4

38. What is the *measured* molarity of the *concentrated* sulphuric acid from the stock bottle?

B
- a. 36.4 mol/L
- 48% b. 18.2 mol/L
- 20% c. 3.64 mol/L
- d. 0.364 mol/L
- 17% e. 0.182 mol/L

5.00 mL aliquot → 500. mL total → take 10.00 mL

in 10.00 mL = 1.821×10^{-3} mol

in 500. mL = x

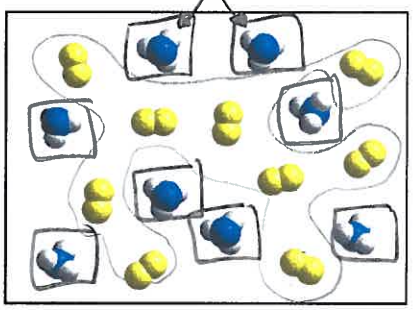
$\therefore x = 0.09101$ mol all came from 5.00 mL stock

$\therefore c = \frac{x}{0.00500\,L} = 18.21$ M.

Part II: The following questions require short answers on this exam paper in the space provided. Be sure to give explanations where required.

39. (10 marks total) The two pictures below show the *gas-phase* reaction between reactants AH_3 and X_2 to form products A_2 and XH_2, where A = dark coloured atoms and X = large, light coloured atoms. The small, light coloured atoms are hydrogen, H.

only 6 used → 9 X_2, 8 AH_3



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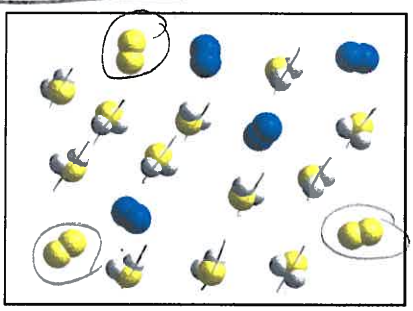

3 X_2, 4 A_2, 12 XH_2

(a) (2 marks) Which reactant is limiting? How can you tell?

2

X_2 is in excess (there were 9 initially but 3 left unused at end). Thus, AH_3 was limiting (all of it was consumed in the reaction)

(b) (2 marks) Write a balanced equation for the reaction. NOT SHOWING EXCESS REACTANT! (worth zero)

2

worth 1 only ⇒ $6\,X_2 + 8\,AH_3 \longrightarrow 4\,A_2 + 12\,XH_2$

OR = $3\,X_2 + 4\,AH_3 \longrightarrow 2\,A_2 + 6\,XH_2$ ⇐ smallest coefficient best choice

(c) (3 marks) The elements A and X are actually real elements to be found between Li and Ne in the periodic table. Identify the reactants AH_3 and X_2 and products A_2 and XH_2, and briefly explain your reasoning.

3

1.0 / 2.0 Reactants: AH_3 = NH_3 and X_2 = O_2

Products: A_2 = N_2 and XH_2 = H_2O

Reasoning: find elements that are diatomic in elemental form: N_2, O_2, F_2, ~~H_2~~ (not this, since H's in molecules h) — possible reactant A_2 + product X_2

Expl. 1.0

- N valence 5, usually forms 3 bonds ⇒ NH_3 (trig. pyramidal, like reactant AH_3)
- O valence 6, usually forms 2 bonds ⇒ H_2O (bent molecule, like product XH_2)
- F valence 7, usually forms only 1 bond → not relevant here

(d) (3 marks) In a real reaction, with the same *proportions* of reactants as shown in the left box, the total pressure of the reactant mixture was 1.00 atm. If the temperature and container volume are not changed, what should the pressure be in the container after the reaction? Explain briefly.

If no mention of MOLES (only T, V), worth 0

3

① Total moles of gas = 17 mol · y ⇒ P = 1.00 atm } y would scale up/down to real amounts

② After rxn, have 19 mol · y ⇒ x = ?

Calc 2.0 expl. 1.0

$\frac{P_1}{n_1} = \frac{P_2}{n_2}$ ⇒ $x = \frac{(y)(19\ \text{mol})(1.00\ \text{atm})}{(y)(17\ \text{mol})} \doteq 1.12\ \text{atm}$

If the gas mixture behaves ideally, then the pressure generated by the gas should be linearly proportional to the number of moles of gas: $PV = nRT$ (Avogadro's law) So, if T & V are held constant, $\frac{P_1}{n_1} = \frac{P_2}{n_2}$.

$\frac{P_1}{n_1} = \left(\frac{RT}{V}\right) = \frac{P_2}{n_2}$

10

Part III: Answer the following questions with complete written answers on this exam paper. Use the blank pages (p.11-12) if you need more space. *Be sure to provide adequate explanations or details to justify you answers where it is appropriate*. No explanation - half-marks *max*!

40. (14 marks total) The following reaction can be used to prepare iodine in the laboratory:

$$2\,NaI(s) + 2\,H_2SO_4(aq) + MnO_2(s) \rightarrow Na_2SO_4(aq) + MnSO_4(aq) + I_2(g) + 2\,H_2O(\ell)$$

(+1 -1) (+4 2(-2)) (+2 -2) (0)

OOPS, SOLID. BUT DOES NOT AFFECT THE QUESTION.

2 (a) (2 marks) What are the names of the following two compounds?

MnO_2 manganese (IV) oxide ✓ Na_2SO_4: sodium sulphate ✓

2 (b) (2 marks) What is the oxidizing agent, and what has been oxidized?

Oxidizing Agent (steals e^-): Mn (+IV) in MnO_2 ✓ Oxidized (loses e^-): iodide I^- in NaI ✓

Only element names, worth ½

2 (c) (2 marks) What is the reducing agent, and what has been reduced?

Reducing agent (gives e^-): iodide I^- in NaI Reduced (takes e^-): Mn (+IV) in MnO_2

(d) (6 marks) What mass of iodine can be obtained if 20.0 g of NaI is mixed with 10.0 g of MnO_2 and treated with an excess of sulphuric acid?

1 + 2

$$n_{NaI} = \frac{20.0\ g}{149.89\ g/mol} = 0.1334\ mol$$

$$n_{MnO_2} = \frac{10.0\ g}{86.938\ g/mol} = 0.1150\ mol$$

Have:		Need:
1.16 ← NOT ENOUGH (LIMITING)		2 mol NaI
1		1 mol MnO_2

6 Alternative approach: to use all the NaI, how much MnO_2 is needed?

to use 0.1334 mol NaI / need x mol MnO_2 = for 2 mol NaI / require 1 mol MnO_2 ⇒ $x = 0.0667$ mol MnO_2

have more than this so can use all the NaI

2 Calculate yield based on using up the limiting reactant (NaI):

$$\frac{0.1334\ mol\ NaI}{2\ mol\ NaI} = \frac{x\ mol\ I_2}{1\ mol\ I_2} \Rightarrow x = 0.0667\ mol\ I_2$$

1.0

$$mass_{I_2} = n_{I_2} \times MM_{I_2}$$
$$= (0.0667\ mol)(253.80\ g/mol)$$
$$= 16.93\ g$$
$$= 16.9\ g\ I_2 \text{ expected (theoretical yield)}$$

✓SF

2 (e) (2 marks) After the reaction, if 14.3 g of solid I_2 were actually isolated, what was the reaction's percent yield?

$$\%\ yield = \frac{actual}{theoretical} \times 100 = \frac{14.3\ g}{16.9\ g} \times 100$$
$$= 84.5\ \%\ ✓\ SF$$

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