

Final Exam  
**ANALYTICAL CHEMISTRY**  
Fall 2024

**Points of attention:**

- For each question, the maximum earned points are specified in the question.
- Write clearly! Answers that are not readable are not marked and don't earn marks!
- All answers should be written in English using **blue or black pens** only.
- Use the pencil only for diagrams and graphs.
- Show all the calculation steps in the given space.
- When finished, submit the question paper, together with the answer scripts and the signed cover page to the invigilator.
- Any cheating/copying may result in an instant failing of the examination.

**Exam Duration:** 2 hours

**Instructor's Name:**

**Exam Date:** 05/01/2024

**Program:** PE

	<b>40</b>
	<b>10</b>

**Student Information**

Name:

ID:

Signature:

**Invigilator**

Initials:

Student ID checked

Time received:

**Question 1****[6 marks]**

Answer all the questions below:

Pure hexane has negligible ultraviolet absorbance above a wavelength of 200 nm. A solution prepared by dissolving 25.8 mg of benzene ( $C_6H_6$ ) in hexane and diluting to 250.0 mL had an absorption peak at 256 nm and an absorbance of 0.266 in a 1.000 cm cell.

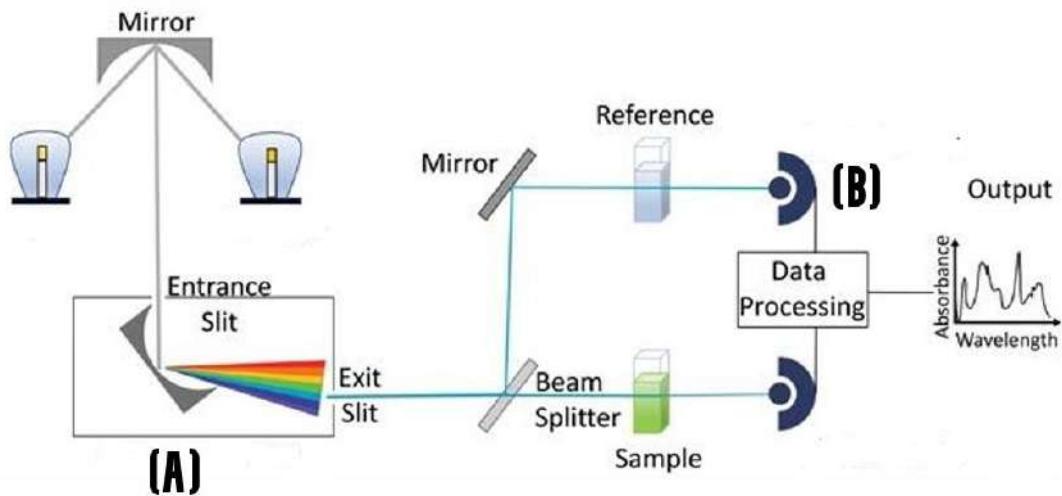
(a) Define UV-Vis Spectrophotometer. (2)

(b) Find the molar absorptivity of benzene at this wavelength. (2)

(c) During a gravimetric analysis of the same solution, the benzene was extracted and dried, yielding a residue of 0.0235 g. Verify whether the concentration determined gravimetrically matches the concentration based on UV-Vis spectrophotometric measurements. (2)

**Question 2****[20 marks]**

UV-Vis spectroscopy plays a critical role in monitoring the concentration of chemical substances, ensuring product quality, and optimizing production workflows.



(Daniel C. Harris, 2015)

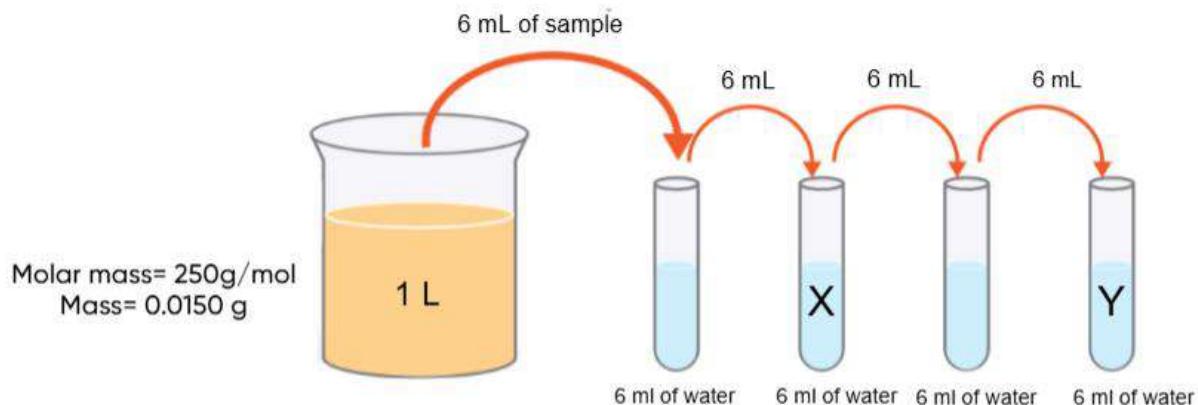
(a) Explain the working principle of a spectrophotometer in detail.

(4)

**(b)** Identify components (A) and (B) in the UV-Vis spectrometer diagram. Explain their specific roles in spectrochemical analysis. (4)

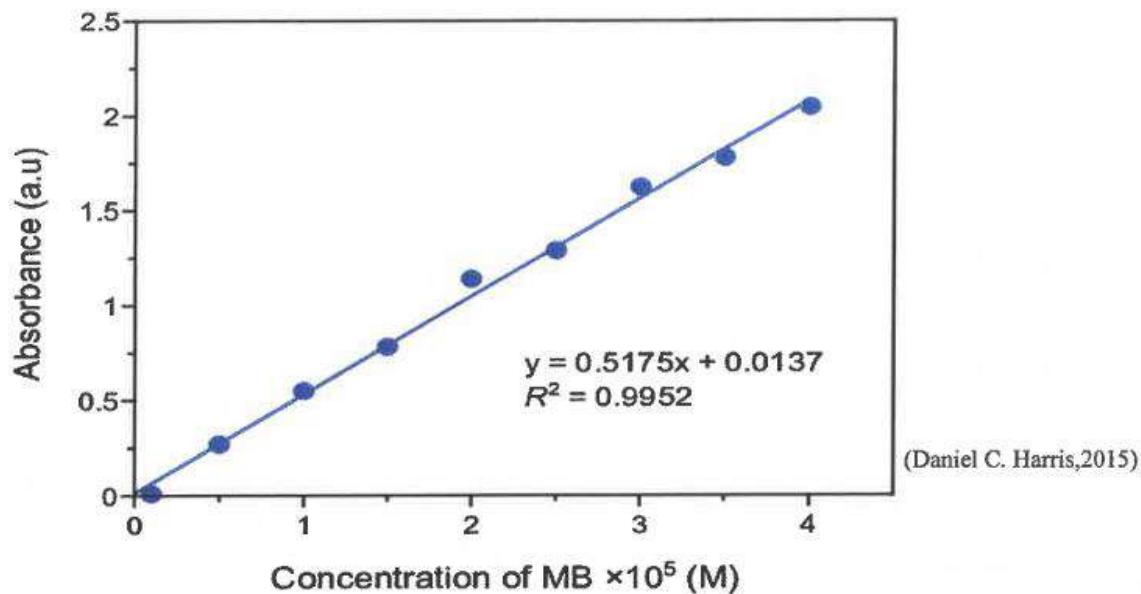
**(c)** Identify the types of radiation emitted by each lamp (UV or visible) in the diagram and explain the difference between the two types of radiation. (3)

(d) Analyze the figure below, which illustrates the preparation of standard solutions for UV-Vis analysis. Using the given information, calculate the concentrations of samples X and Y. (5)



(trinset, 2024)

(e) The calibration curve shown below prepared using a standard solution, is utilized for quality control and process optimization in industrial applications involving methylene blue.

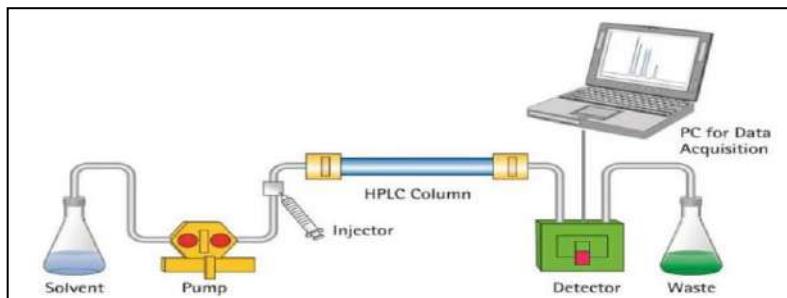


i. Explain the purpose of a calibration curve and describe how to construct one using a standard solution. (2)

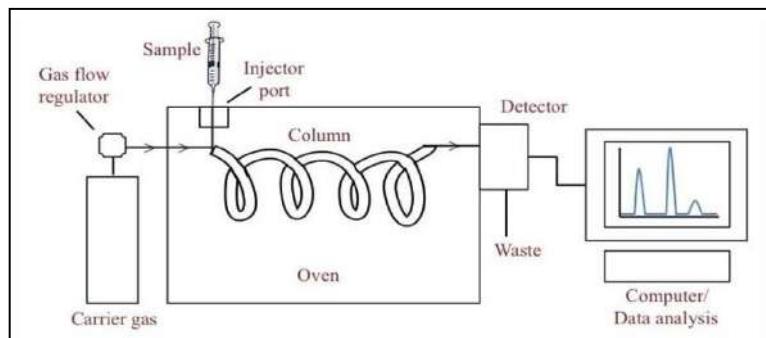
ii. A methylene blue sample solution has an absorbance of 0.528 (a.u.) after being diluted by a factor of two. Calculate the concentration of the original solution before dilution. (2)

**Question 3****[6 marks]**

Chromatography is a fundamental technique in analytical chemistry. Refer to the diagrams labeled A and B, which represent two types of instrumental chromatography, and answer the following:



(Daniel C. Harris, 2015)

**(A)**

(Daniel C. Harris, 2015)

**(B)**

**(a)** Identify the techniques represented in diagrams A and B.

(2)

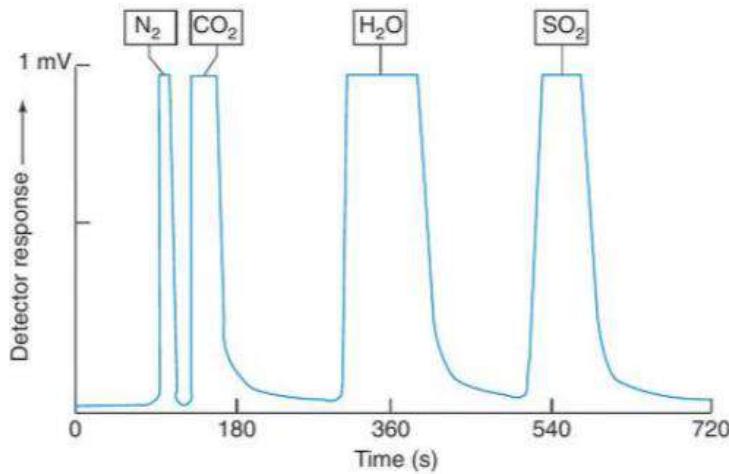
**(b)** Explain the working principles of technique B.

(2)

**(c)** Compare the two techniques, highlighting their key differences. (2)

**Question 4****[ 4 marks]**

An elemental analyzer is used to determine the composition of a coal sample before it is used in a power plant. The chromatogram shows peaks for  $\text{N}_2$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{SO}_2$ .



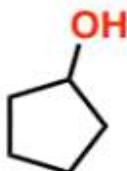
(Daniel C. Harris, 2015)

- Based on the diagram, Calculate the retention time for each compound ( $\text{N}_2$ ,  $\text{CO}_2$ , and  $\text{SO}_2$ ).
- Find the relative retention ( $\alpha$ ).

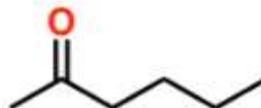
## Question 5

[4 marks]

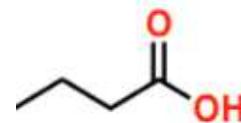
Among the three organic compounds (cyclopentanol, 2-hexanone, and carboxylic acid) identify which molecule corresponds to the IR spectrum (1) and which corresponds to the IR spectrum (2). Provide reasoning based on key functional group absorptions observed in the spectra.



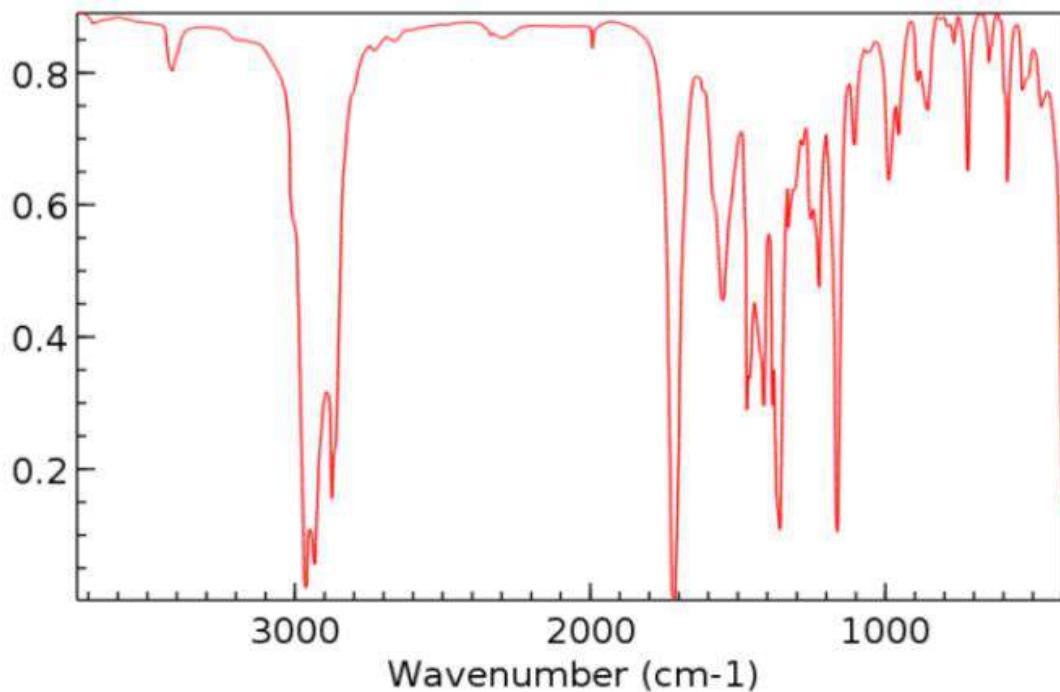
cyclopentanol



2-hexanone

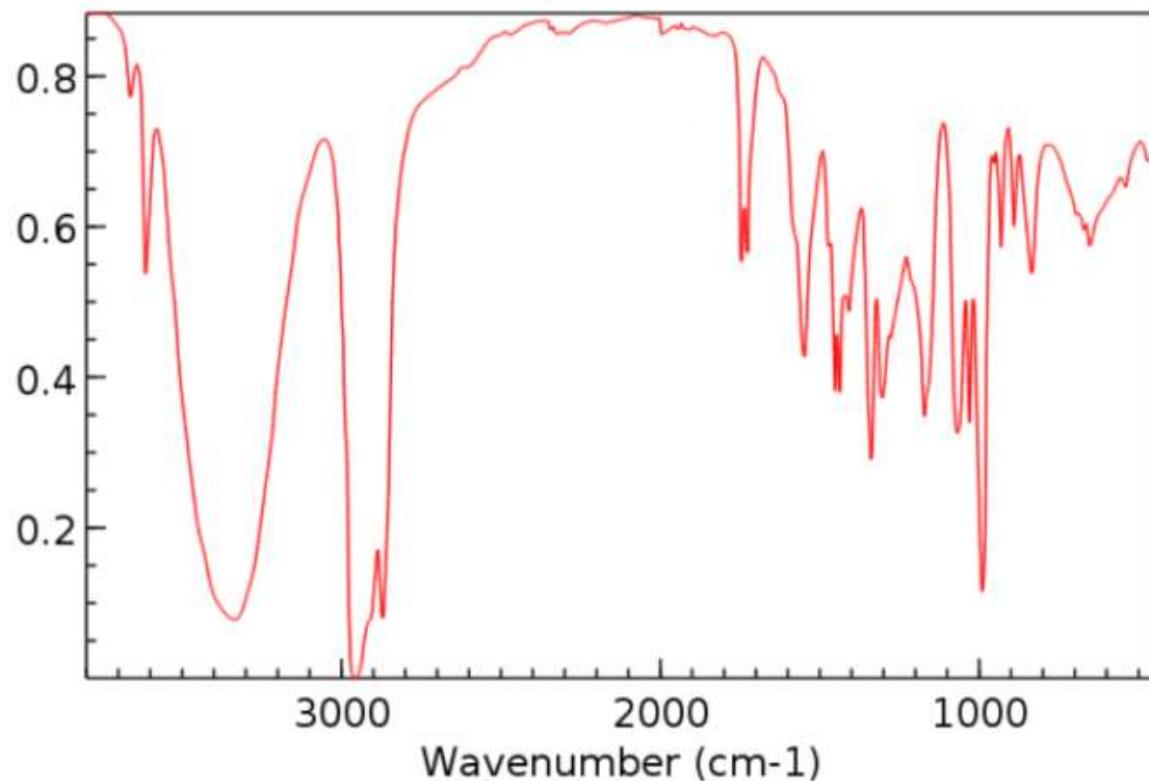


carboxylic acid



(Ashenhurst, 2016)

(1)



(Ashenhurst, 2016)

**(2)**

Functional Group	Wavenumber Range (cm <sup>-1</sup> )
O–H (Alcohol)	3200 - 3600
O–H (Carboxylic Acid)	2500 - 3300
C–H (Alkanes)	2800 - 3000
C–H (Alkenes)	3000 - 3100
C–H (Aromatic)	3000 - 3100
C=O (Ketone)	1650 - 1750
C=O (Aldehyde)	1700 - 1750
C=O (Carboxylic Acid)	1700 - 1725
C=O (Ester)	1735 - 1750
N–H (Amine/Amide)	3300 - 3500
C≡C (Alkyne)	2100 - 2260
C≡N (Nitrile)	2200 - 2260
C=C (Alkene)	1600 - 1680
C–O (Ester, Ether)	1000 - 1300
Aromatic Rings	1450 - 1600

# Periodic Table of the Elements

1	<b>H</b> Hydrogen 1.008	2	<b>He</b> Helium 4.003
3	<b>Li</b> Lithium 6.941	4	<b>Be</b> Beryllium 9.012
11	<b>Na</b> Sodium 22.990	12	<b>Mg</b> Magnesium 24.305
19	<b>K</b> Potassium 39.098	20	<b>Ca</b> Calcium 40.078
37	<b>Rb</b> Rubidium 84.468	38	<b>Sr</b> Strontium 87.62
55	<b>Cs</b> Cesium 132.905	56	<b>Ba</b> Barium 137.327
87	<b>Fr</b> Francium 223.020	88	<b>Ra</b> Radium 226.025
13	<b>B</b> Boron 10.811	21	<b>Sc</b> Scandium 44.956
39	<b>Y</b> Yttrium 88.906	40	<b>Ti</b> Titanium 47.88
57	<b>Hf</b> Hafnium 178.49	58	<b>Zr</b> Zirconium 91.224
89	<b>Rf</b> Rutherfordium [261]	90	<b>Ta</b> Tantalum 180.948
143	<b>Ra</b> Actinides [Actinium 227.028]	144	<b>W</b> Tungsten 183.85
145	<b>Fr</b> Actinides [Actinium 227.028]	146	<b>Db</b> Dubnium [262]
147	<b>Ra</b> Actinides [Actinium 227.028]	148	<b>Sg</b> Seaborgium [266]
149	<b>Ra</b> Actinides [Actinium 227.028]	150	<b>Bh</b> Bohrium [264]
151	<b>Ra</b> Actinides [Actinium 227.028]	152	<b>Ds</b> Darmstadtium [269]
153	<b>Ra</b> Actinides [Actinium 227.028]	154	<b>Rg</b> Roentgenium [272]
155	<b>Ra</b> Actinides [Actinium 227.028]	156	<b>Cn</b> Copernicium [277]
157	<b>Ra</b> Actinides [Actinium 227.028]	158	<b>Uut</b> Ununtrium [289]
159	<b>Ce</b> Cerium 140.115	160	<b>Pm</b> Promethium 144.908
161	<b>Pr</b> Praseodymium 140.115	162	<b>Sm</b> Samarium 150.36
163	<b>Eu</b> Europium 151.966	164	<b>Gd</b> Gadolinium 157.25
165	<b>Tb</b> Terbium 158.925	166	<b>Dy</b> Dysprosium 162.50
167	<b>Ho</b> Holmium 164.930	168	<b>Er</b> Erbium 167.26
169	<b>Tm</b> Thulium 168.934	170	<b>Yb</b> Ytterbium 173.04
171	<b>Lu</b> Lutetium 174.967	172	<b>Y</b> Yttrium 18.998
173	<b>La</b> Lanthanum 138.906	174	<b>O</b> Oxygen 15.999
175	<b>Ce</b> Cerium 140.115	176	<b>F</b> Fluorine 18.998
177	<b>Pr</b> Praseodymium 144.908	178	<b>Ne</b> Neon 20.180
179	<b>Nd</b> Neodymium 144.24	180	<b>N</b> Nitrogen 14.007
181	<b>P</b> Phosphorus 30.974	182	<b>S</b> Sulfur 32.066
183	<b>Si</b> Silicon 28.086	184	<b>Cl</b> Chlorine 35.453
185	<b>Al</b> Aluminum 26.982	186	<b>Ar</b> Argon 39.948
187	<b>Ge</b> Germanium 65.39	188	<b>Kr</b> Krypton 84.80
189	<b>Zn</b> Zinc 65.39	190	<b>Br</b> Bromine 79.904
191	<b>Cu</b> Copper 63.546	192	<b>Se</b> Selenium 78.09
193	<b>Ni</b> Nickel 58.693	194	<b>As</b> Arsenic 74.922
195	<b>Co</b> Cobalt 58.933	196	<b>Ge</b> Germanium 69.732
197	<b>Fe</b> Iron 55.933	198	<b>Ge</b> Germanium 72.61
199	<b>Mn</b> Manganese 54.938	200	<b>Ge</b> Germanium 72.61
201	<b>Cr</b> Chromium 51.996	202	<b>Ge</b> Germanium 72.61
203	<b>V</b> Vanadium 50.942	204	<b>Ge</b> Germanium 72.61
205	<b>Ti</b> Titanium 47.88	206	<b>Ge</b> Germanium 72.61
207	<b>Sc</b> Scandium 44.956	208	<b>Ge</b> Germanium 72.61
209	<b>Ca</b> Calcium 40.078	210	<b>Ge</b> Germanium 72.61
211	<b>Na</b> Sodium 22.990	212	<b>Ge</b> Germanium 72.61
213	<b>K</b> Potassium 39.098	214	<b>Ge</b> Germanium 72.61
215	<b>Rb</b> Rubidium 84.468	216	<b>Ge</b> Germanium 72.61
217	<b>Sr</b> Strontium 87.62	218	<b>Ge</b> Germanium 72.61
219	<b>Cs</b> Cesium 132.905	220	<b>Ge</b> Germanium 72.61
221	<b>Ba</b> Barium 137.327	222	<b>Ge</b> Germanium 72.61
223	<b>Fr</b> Francium 223.020	224	<b>Ge</b> Germanium 72.61
225	<b>Ra</b> Radium 226.025	226	<b>Ge</b> Germanium 72.61
227	<b>Fr</b> Francium 223.020	228	<b>Ge</b> Germanium 72.61

57	<b>La</b> Lanthanum 138.906	58	<b>Ce</b> Cerium 140.115	59	<b>Pr</b> Praseodymium 140.908	60	<b>Nd</b> Neodymium 144.913	61	<b>Pm</b> Promethium 144.24	62	<b>Sm</b> Samarium 150.36	63	<b>Eu</b> Europium 151.966	64	<b>Gd</b> Gadolinium 157.25	65	<b>Tb</b> Terbium 158.925	66	<b>Dy</b> Dysprosium 162.50	67	<b>Ho</b> Holmium 164.930	68	<b>Er</b> Erbium 167.26	69	<b>Tm</b> Thulium 168.934	70	<b>Yb</b> Ytterbium 173.04	71	<b>Lu</b> Lutetium 174.967
89	<b>Ac</b> Actinium 227.028	90	<b>Th</b> Thorium 232.038	91	<b>Pa</b> Protactinium 231.036	92	<b>U</b> Uranium 238.029	93	<b>Np</b> Neptunium 237.048	94	<b>Pu</b> Plutonium 244.064	95	<b>Am</b> Americium 243.061	96	<b>Cm</b> Curium 247.070	97	<b>Bk</b> Berkelium 247.070	98	<b>Cf</b> Californium 251.080	99	<b>Es</b> Einsteinium 257.095	100	<b>Fm</b> Fermium 251.080	101	<b>Md</b> Mendelevium 258.1	102	<b>No</b> Nobelium 259.101	103	<b>Lr</b> Lawrencium 262.028

## Reference:

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[https://www.printablee.com/post\\_periodic-table-of-elements-printable\\_400652/](https://www.printablee.com/post_periodic-table-of-elements-printable_400652/)

**MLO and Bloom's Level of Complexity**

Q #	MLO Addressed	Complexity Level	Mark	Remark
1	1,3	Analyzing, Evaluating	6	
2	1,2,3	Understanding/Application/Analyzing	20	
3	2	Application	6	
4	1,3	Application/Analyzing	4	
5	3	Analyzing	4	