



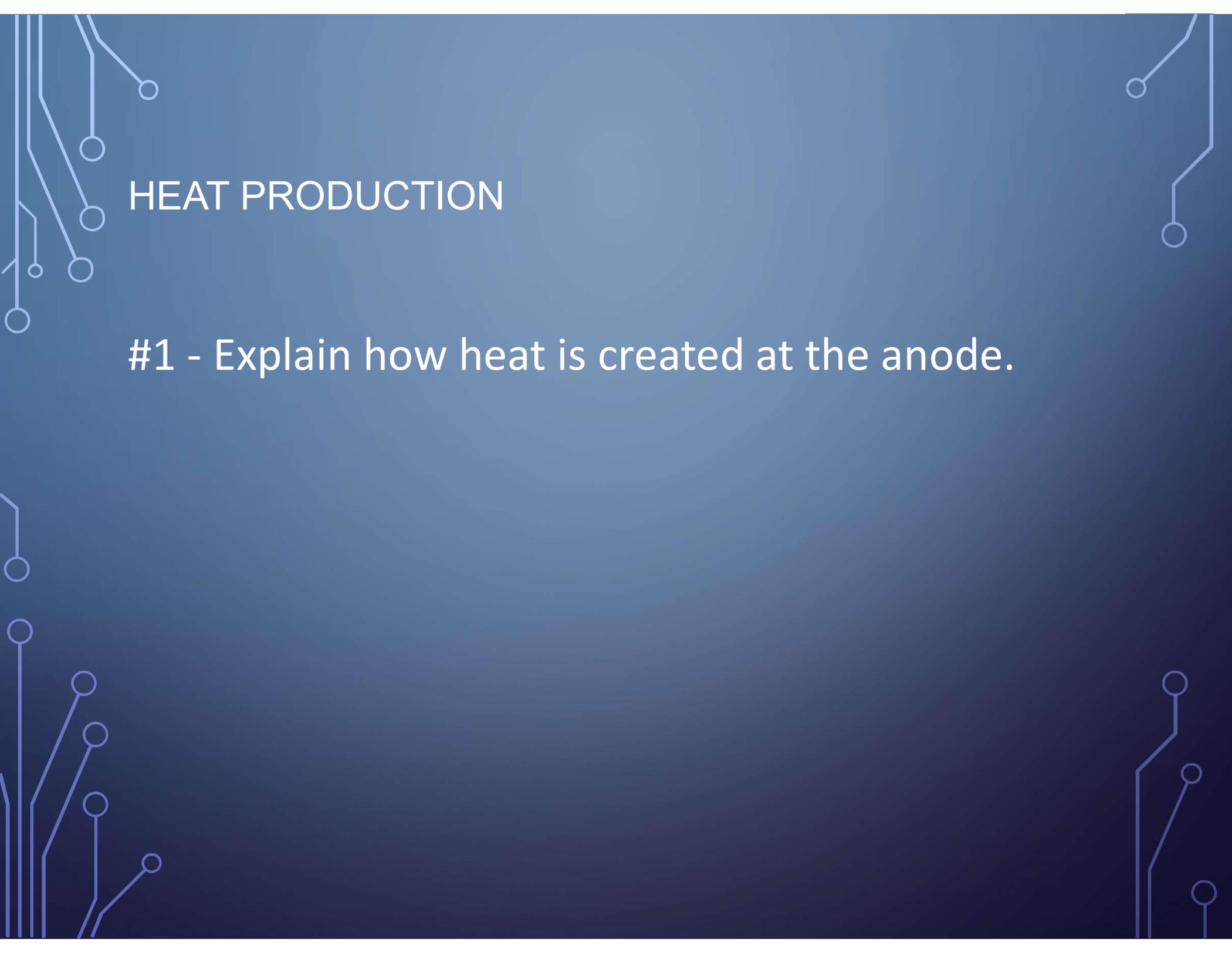
MI132 – IMAGING PRINCIPLES AND EQUIPMENT
2022-2023

UNIT 4
X-RAY PRODUCTION, FILTRATION AND EMISSION
SPECTRUM

READING HOSPITAL SCHOOL OF HEALTH SCIENCES
MEDICAL IMAGING PROGRAM

PHOTONS (TARGET INTERACTIONS) (CONT.)

- Filament electrons interact with target atoms (tungsten) to produce x-rays in the following two ways:
 - Characteristic interactions
 - Bremsstrahlung (brems) interactions
- But the most common interaction results in HEAT!!

A decorative background pattern of light blue circuit board traces and nodes is visible on a dark blue gradient background. The pattern consists of various lines, right-angle turns, and small circles representing solder pads or vias, scattered across the corners and edges of the slide.

HEAT PRODUCTION

#1 - Explain how heat is created at the anode.

X-RAY PHOTONS – CHARACTERISTIC INTERACTIONS

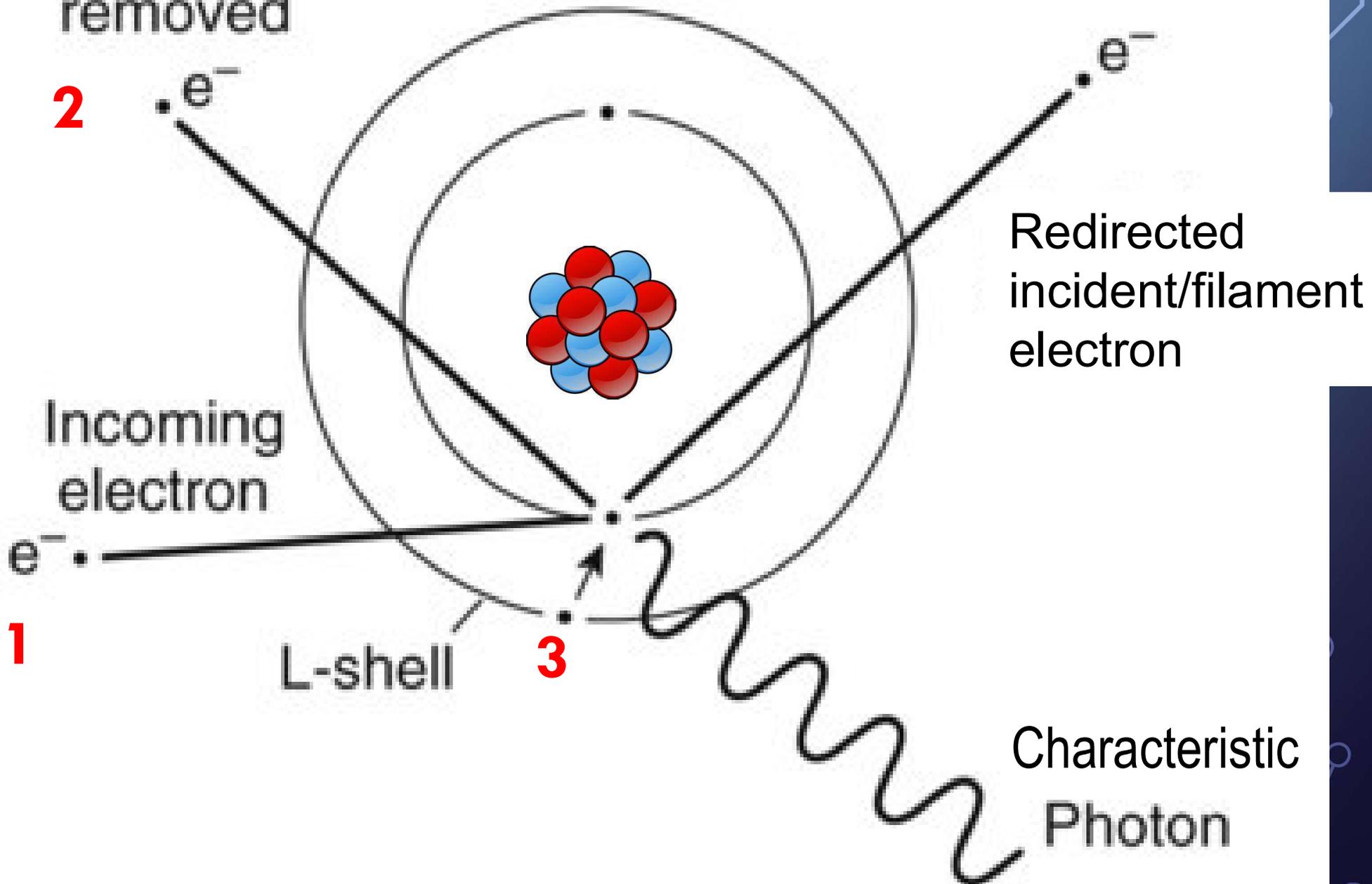
#2 – Explain how a characteristic photon is created.

#3 - Explain how the energy of a characteristic x-ray photon is calculated.

- a. L to K transition
- b. O to K transition
- c. P to K transition
- d. M to L transition
- e. O to L transition

- Get into groups of 2
 - Draw and explain the process
 - Identify which transition resulted in the highest energy x-ray

K-shell electron removed



Redirected incident/filament electron

Incoming electron

Characteristic Photon

L-shell

Characteristic photon

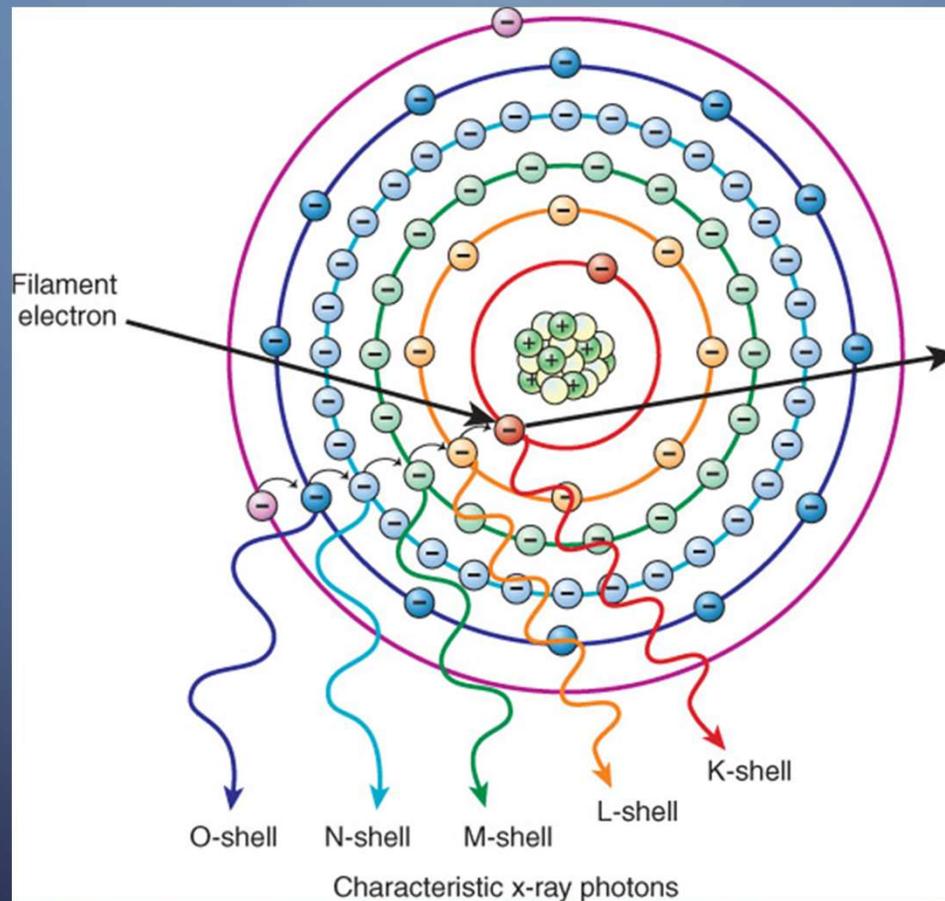
- L to K = 57.4
- O to K = 69.42
- P to K = 69.492
- M to L = 9.28
- O to L = 12.02

K shell	69.5 keV
L shell	12.1 keV
M shell	2.82 keV
N shell	0.6 keV
O shell	0.08 keV
P shell	0.008 keV

- What do you think of the energy of the photons created by the transitions into the L-shell??
- Which characteristic photons do you think are useful?
- Why do you think they are called characteristic photons?
- What would happen to the energy of the characteristic photons if we changed the target material to gold?

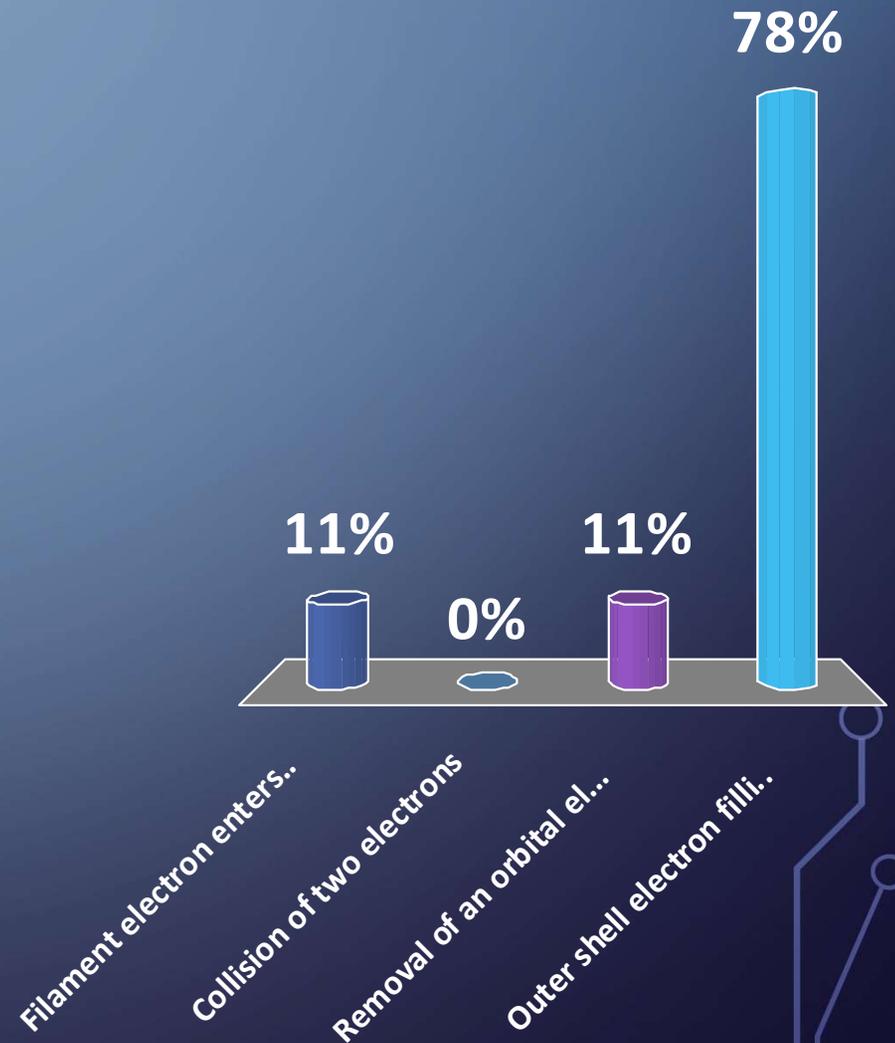
Characteristic Cascade:

#4 - Define characteristic cascade.



AT WHAT POINT IN THE INTERACTION CHAIN OF EVENTS IS A CHARACTERISTIC PHOTON PRODUCED?

- A. Filament electron enters a target atom
- B. Collision of two electrons
- C. Removal of an orbital electron
- D.  Outer shell electron filling inner shell vacancy



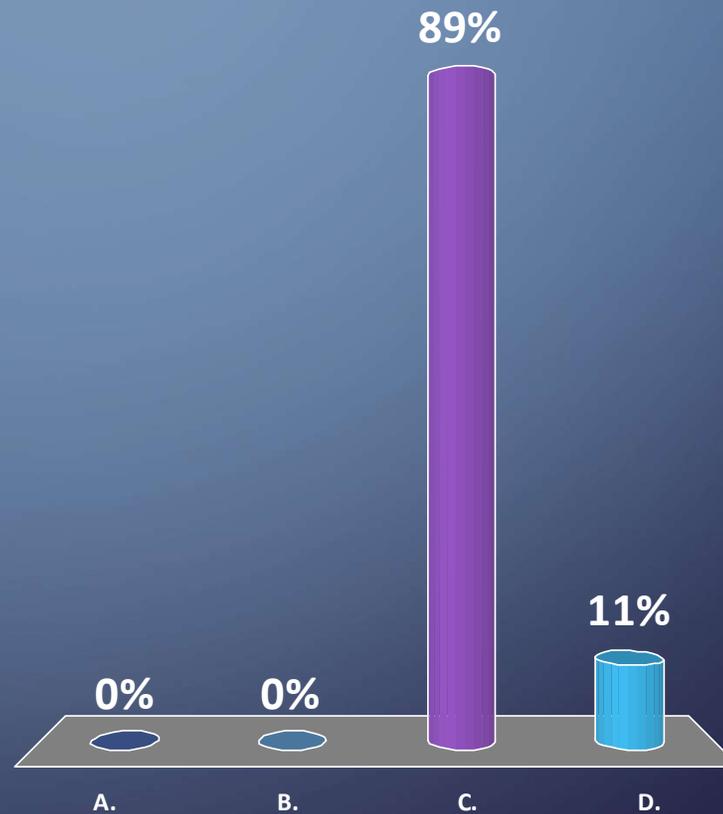
CHARACTERISTIC K-X-RAYS WILL ONLY BE CREATED IF THE KVP IS SET AT _____ OR ABOVE.

A. 50

B. 65

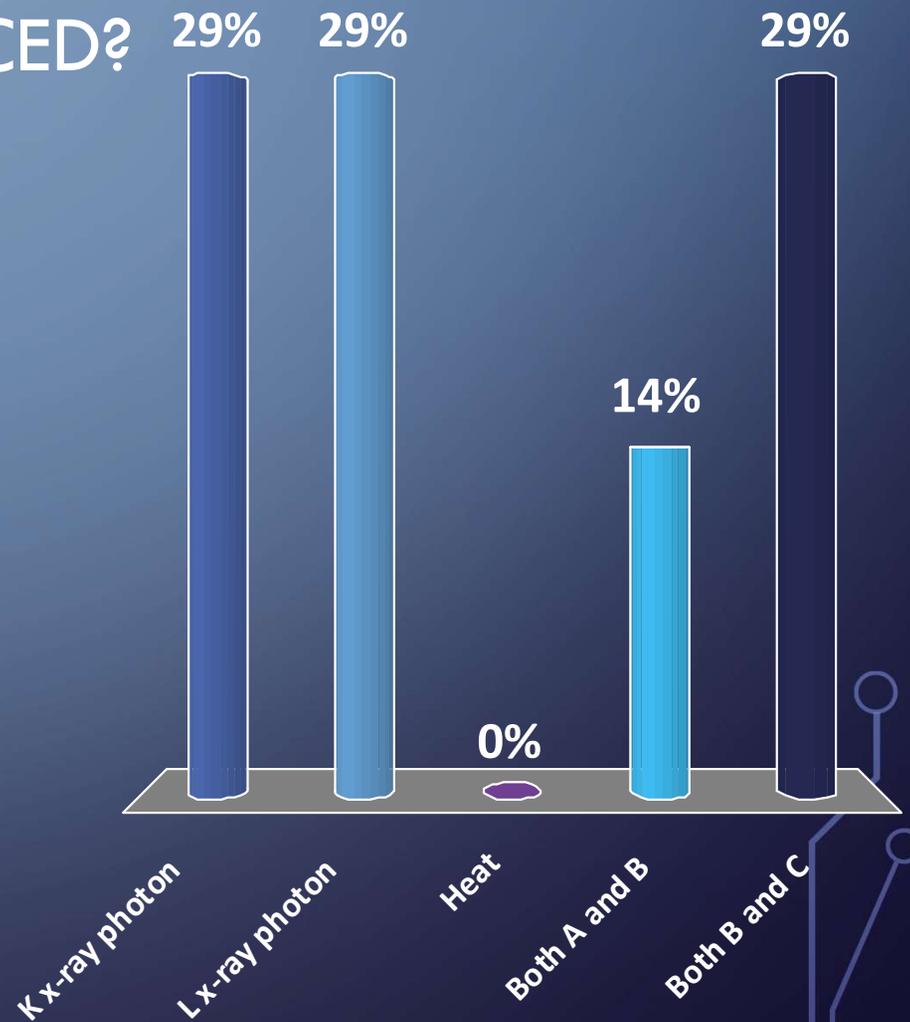
C. 70

D. 80



A FILAMENT E- ENTERS A TUNGSTEN TARGET ATOM WITH 70 KVP OF ENERGY. IT INTERACTS FIRST WITH AN L-SHELL ELECTRON, THEN WITH A K-SHELL ELECTRON. WHICH OF THE FOLLOWING ARE PRODUCED?

- A. K x-ray photon
- B. L x-ray photon
- C. Heat
- D. Both A and B
- ★ E. Both B and C



BREMSSTRAHLUNG

BREMSSTRAHLUNG INTERACTIONS

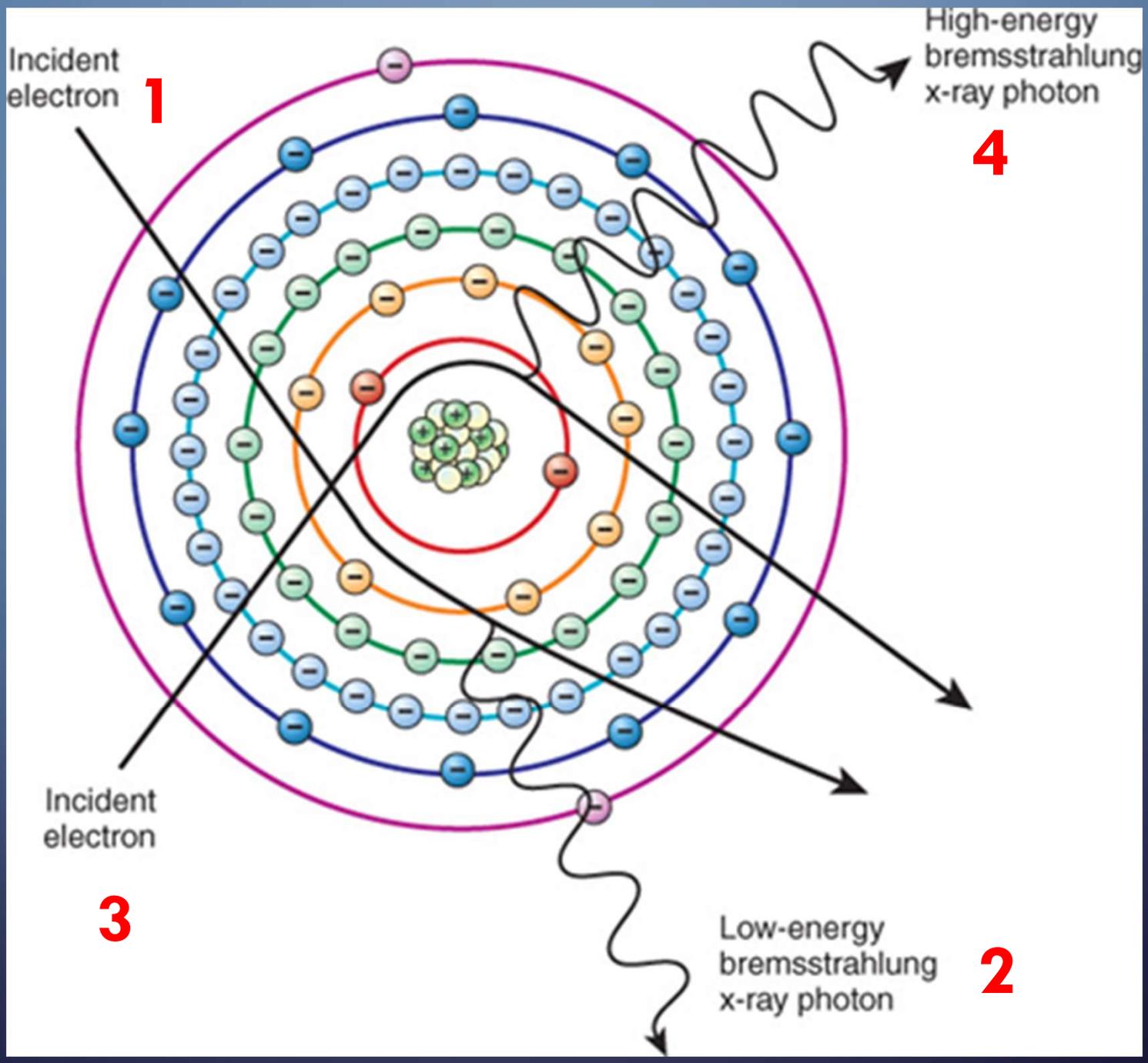
#6 - Explain how bremsstrahlung photons are created.

- Draw the process

BREMSSTRAHLUNG INTERACTIONS

#7 - What is the minimum and maximum energy of a bremsstrahlung photon?

What factor effects this?

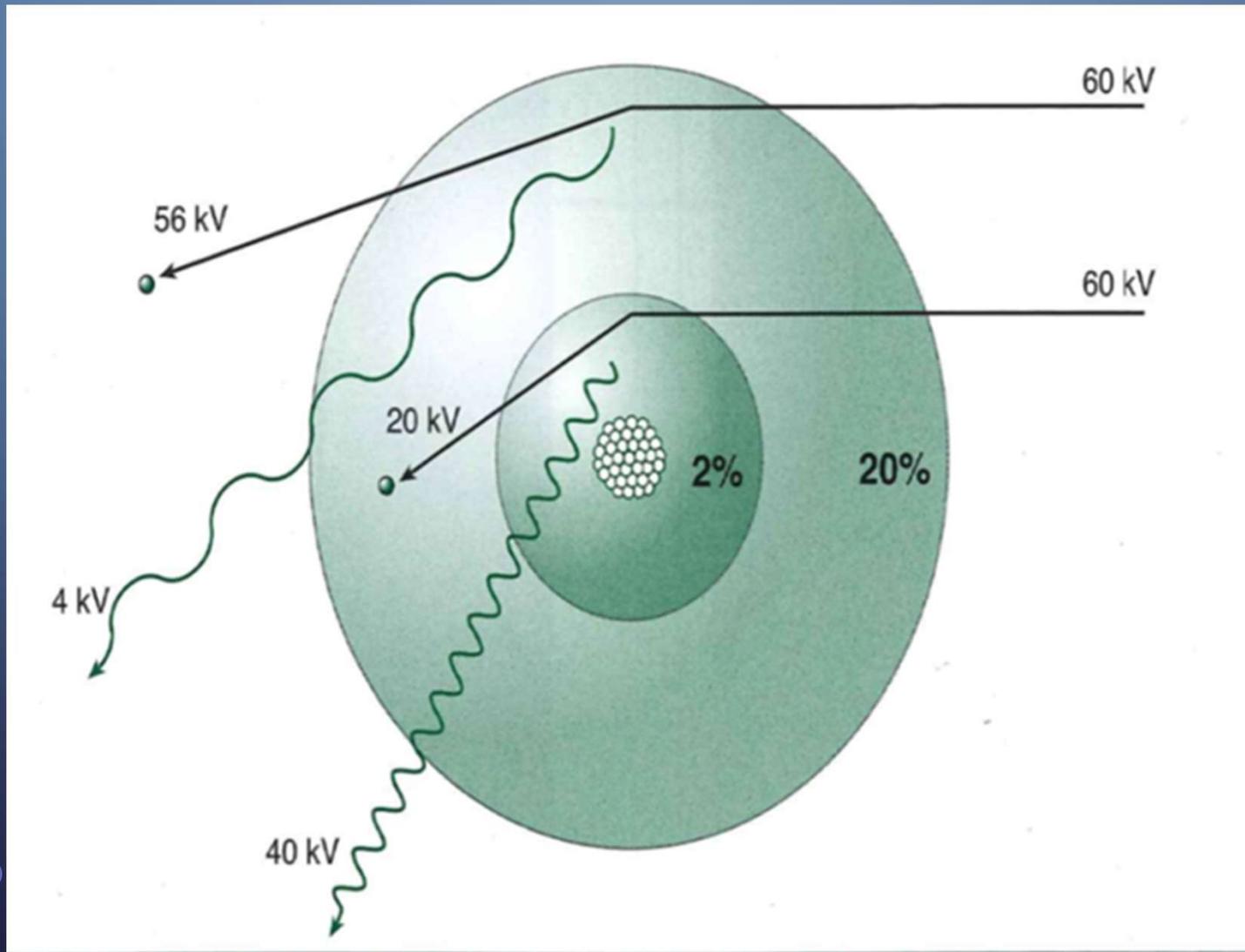


BREMSSTRAHLUNG INTERACTIONS

#8 - If an incident electron enters a tungsten atom with 85 keV and exits with 35 keV of energy, what is the energy of the bremsstrahlung photon created?

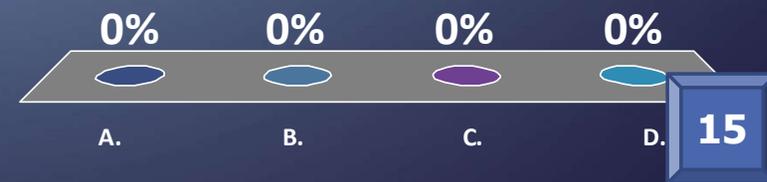
#9 - If an incident electron leaves the anode 5 keV and entered with 85 keV of energy, what is the energy of the bremsstrahlung photon created?

BREMSSTRAHLUNG INTERACTIONS



MOST X-RAYS LEAVING THE TUBE ARE:

- ★A. Bremsstrahlung
- B. Characteristic
- C. Compton
- D. Photoelectric



A KVP SETTING OF 80 WILL RESULT IN WHICH OF THE FOLLOWING BREMSSTRAHLUNG X-RAYS?

A. 60 keV

B. 80 keV

C. 100 keV

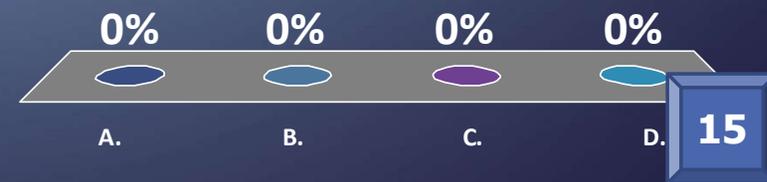
★ D. A and B only

E. All of the above



THE ENERGY OF BREMS X-RAYS ARE:

- A. Distinct energies based on the electron binding energy of the target material
- ★ B. A wide range of energies based on the electrons distance from the nucleus
- C. Always between 0 and 90 keV
- D. Never above 120 keV



A FILAMENT ELECTRON INTERACTS WITH AN OUTER SHELL ELECTRON OF TUNGSTEN BUT DOES NOT REMOVE IT. WHICH OF THE FOLLOWING IS PRODUCED?

- A. 50 keV photon
- B. 70 keV photon
- ★ C. Heat
- D. Brems photon

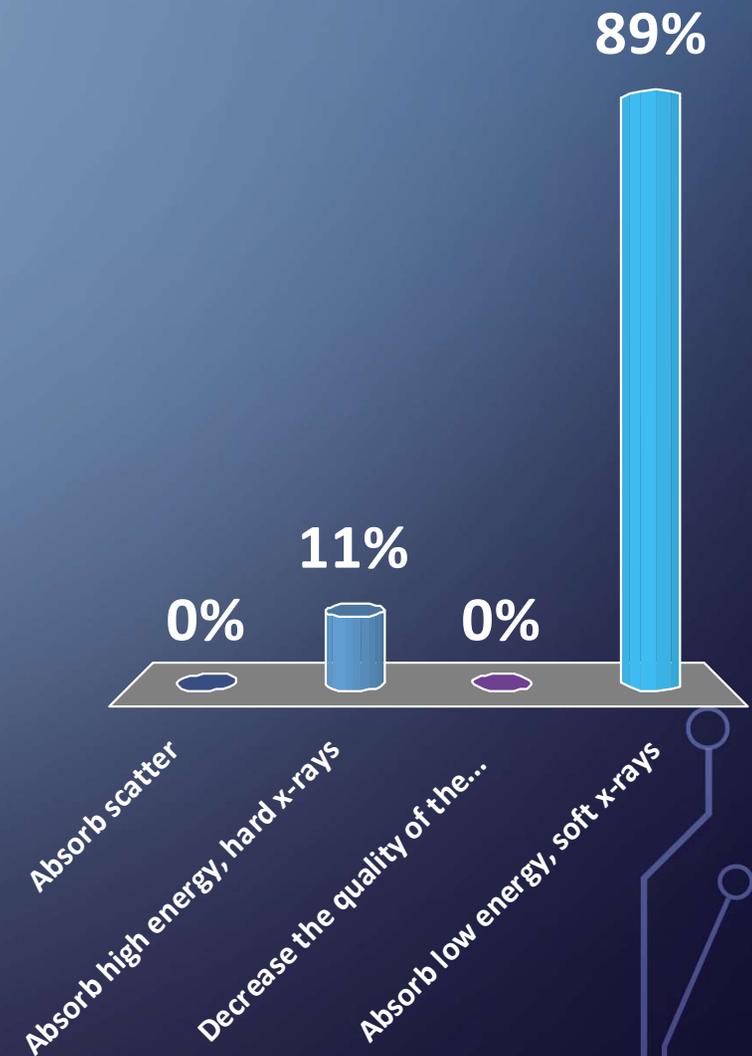


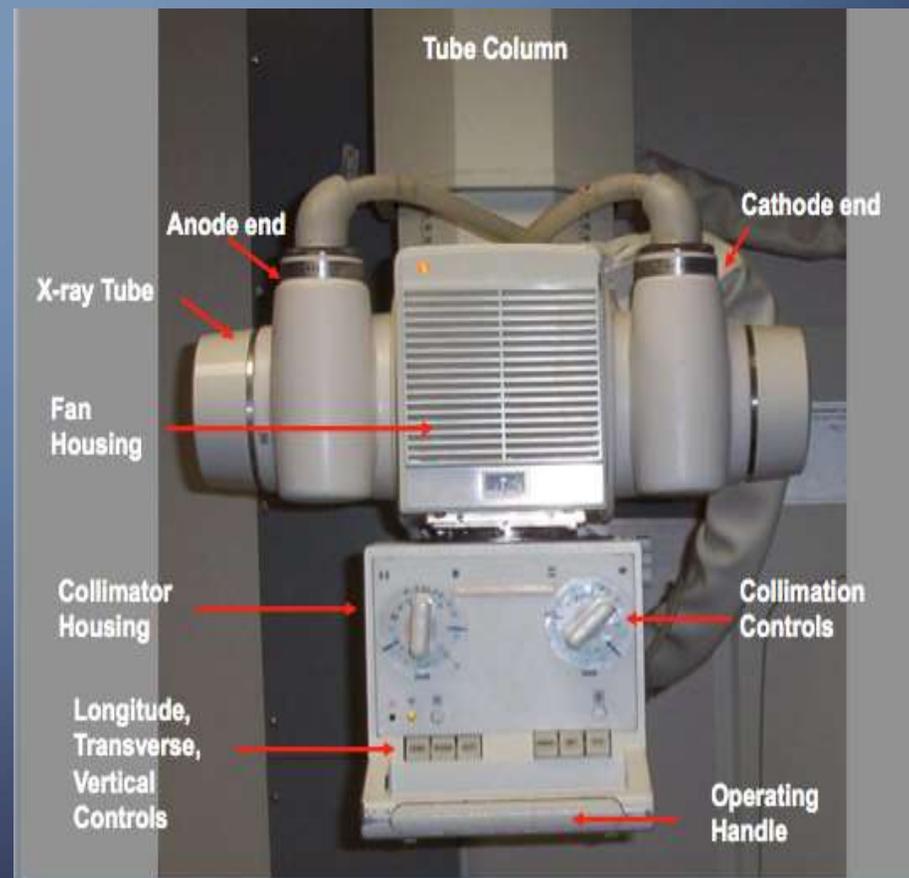
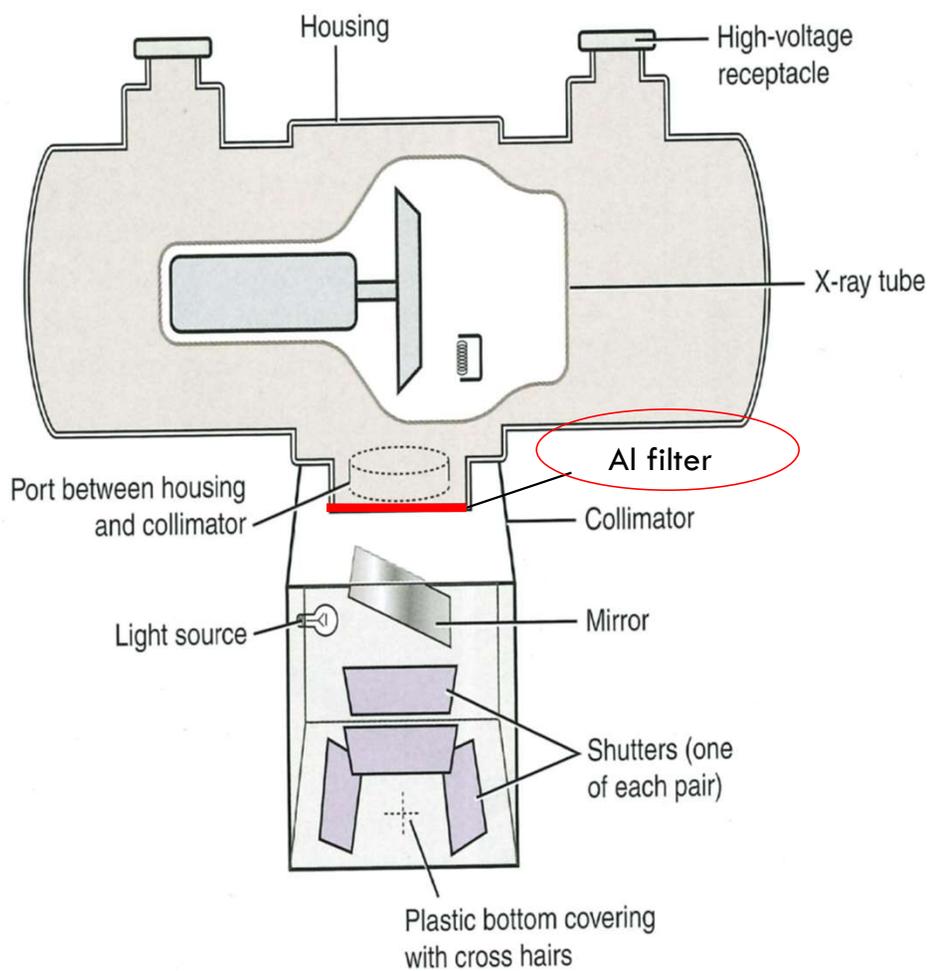
The background is a dark blue gradient. In the four corners, there are white line-art patterns resembling circuit board traces and nodes, extending from the edges towards the center.

FILTRATION & EMISSION SPECTRUM

PURPOSE OF ADDING FILTRATION IS TO:

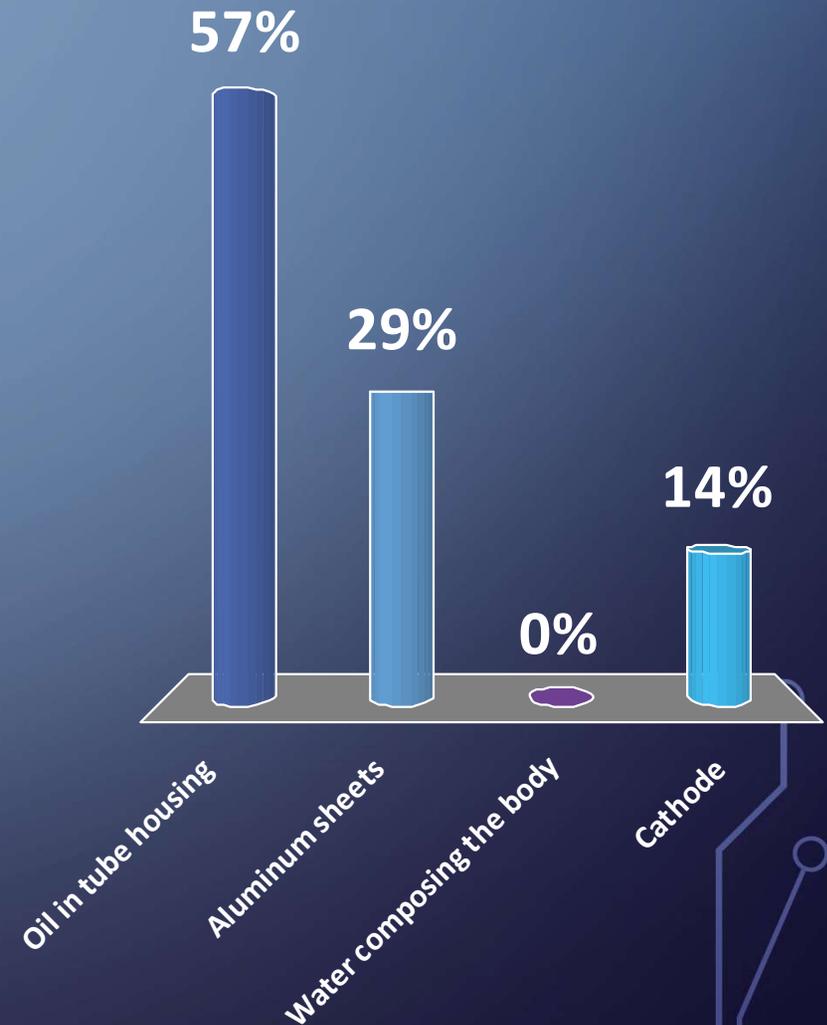
- A. Absorb scatter
- B. Absorb high energy, hard x-rays
- C. Decrease the quality of the beam
- D. Absorb low energy, soft x-rays





WHICH OF THE FOLLOWING IS CONSIDERED INHERENT FILTRATION?

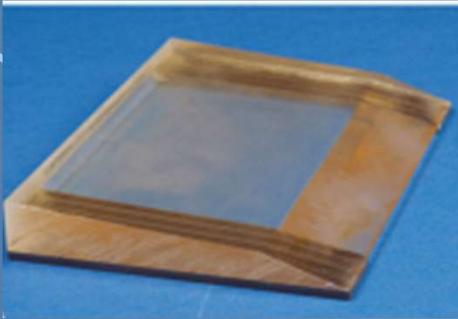
- ★ A. Oil in tube housing
- B. Aluminum sheets
- C. Water composing the body
- D. Cathode



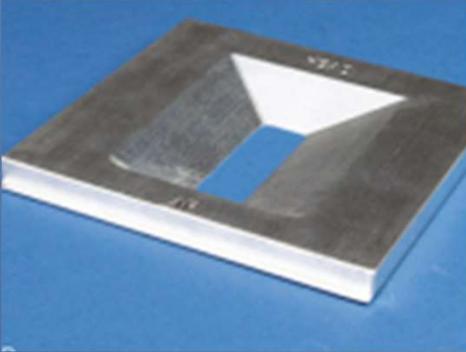
The background is a dark blue gradient. In the corners, there are decorative white line-art patterns resembling circuit board traces and nodes. These patterns are most prominent in the top-left, top-right, and bottom-left corners, with some extending into the bottom-right corner.

Compensating filters

#2 – What is the purpose of compensating filters?



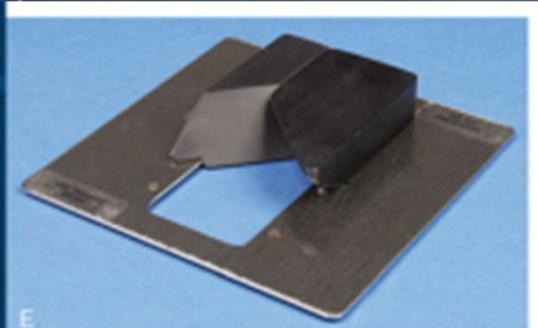
Wedge



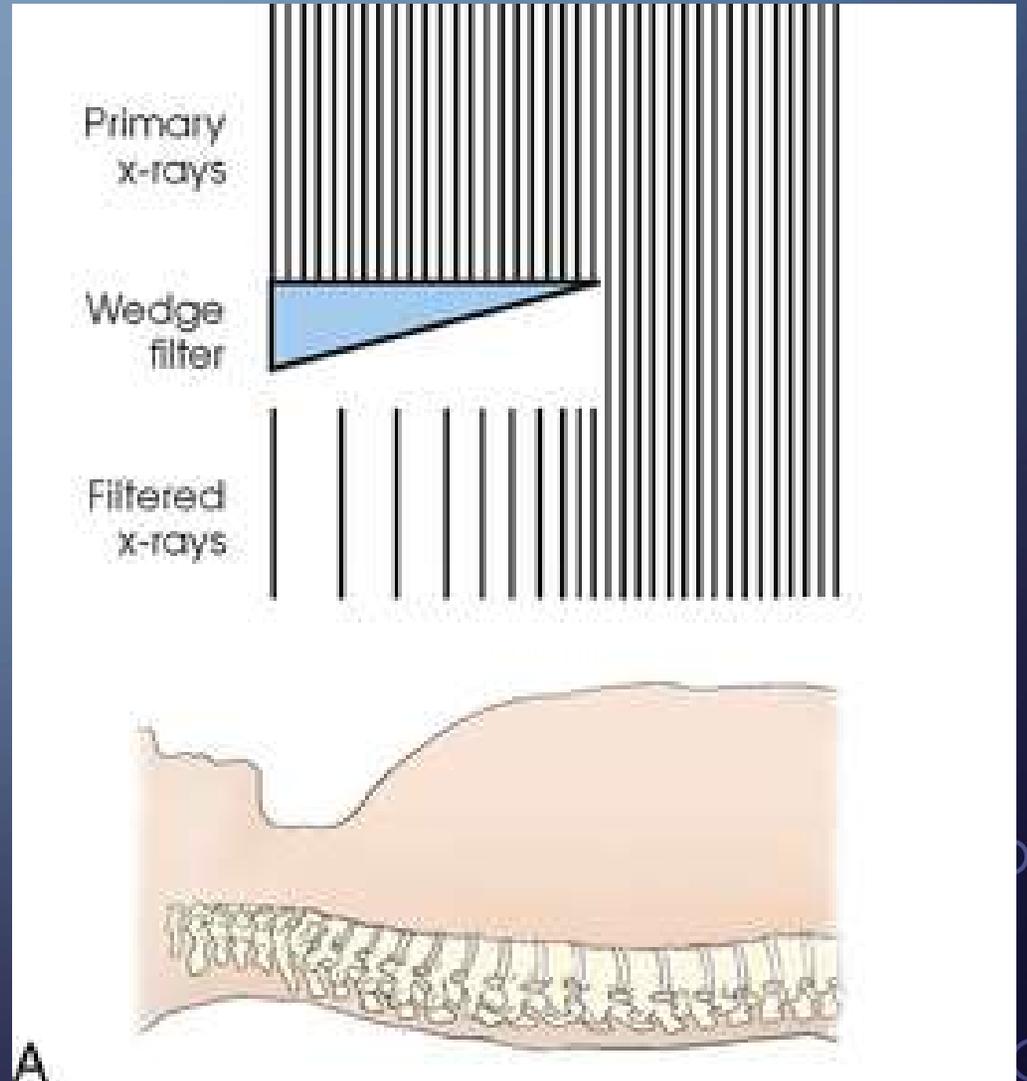
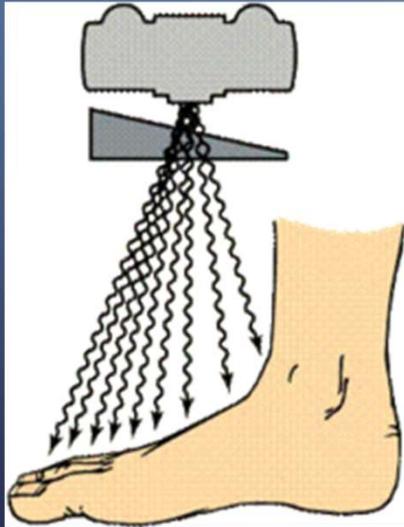
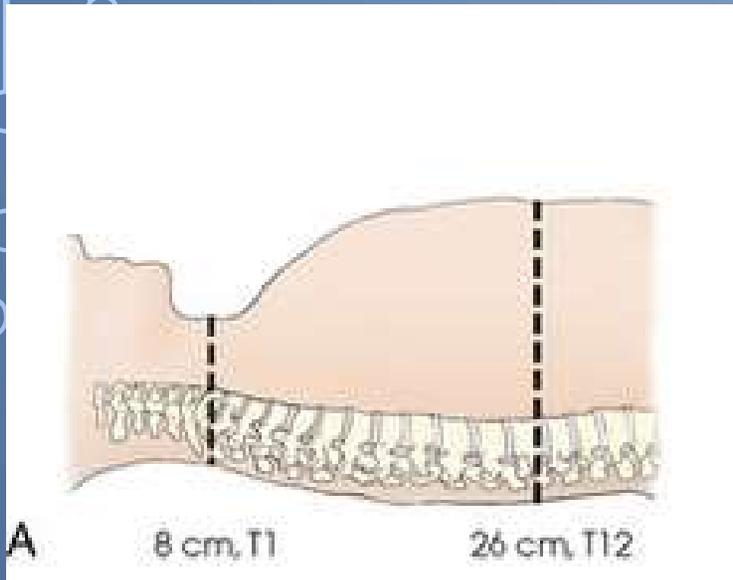
Trough (bilateral wedge)



Boomerang



Ferlic





PROPERTIES OF THE BEAM

#3 - Define beam quantity and beam quality.

BEAM QUANTITY

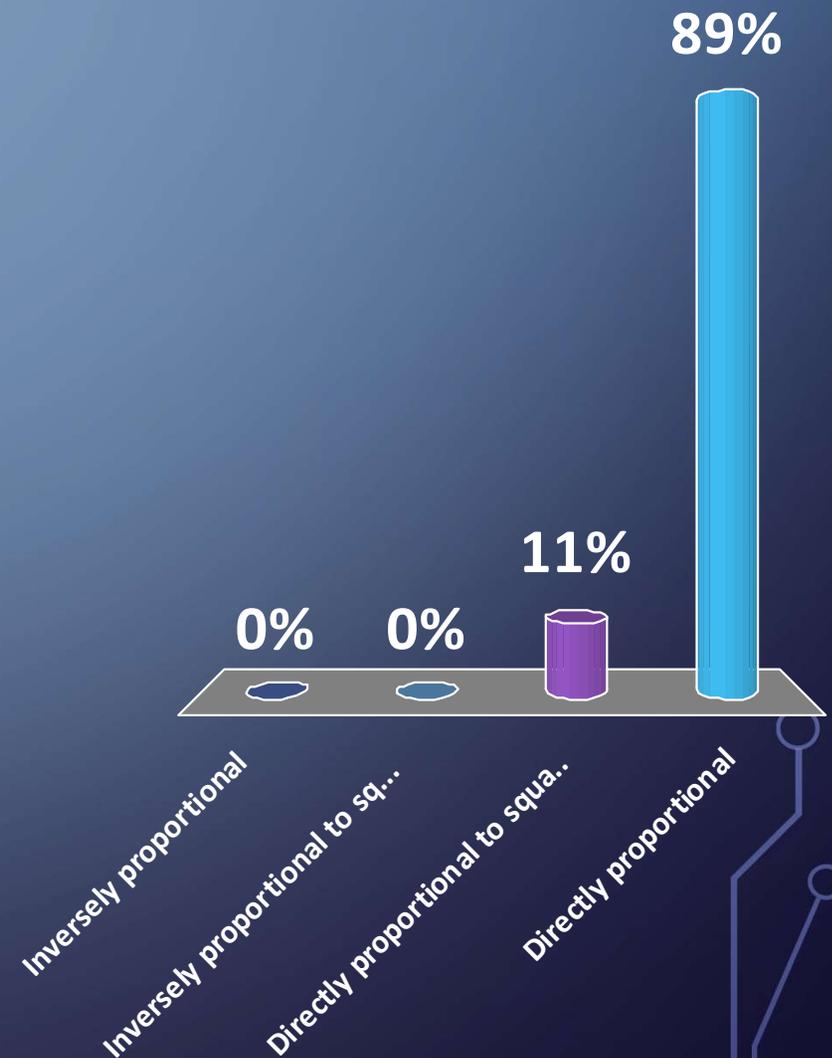
#4 - Identify four factors that influence beam quantity.

a. Explain the relationships that exist between the factors and beam quantity.

mAs
kVp
Distance
Filtration

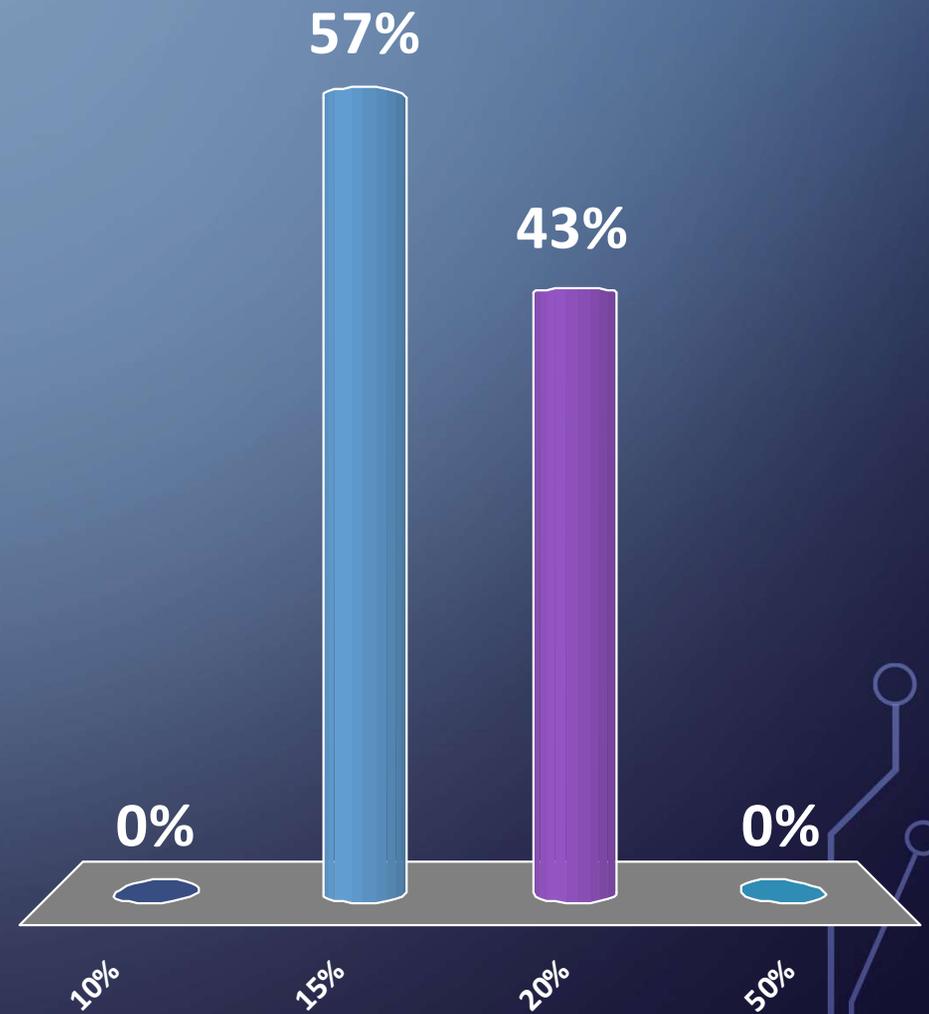
WHAT TYPE OF RELATIONSHIP EXISTS BETWEEN BEAM QUANTITY AND MAS?

- A. Inversely proportional
- B. Inversely proportional to square of the distance
- C. Directly proportional to square of the distance
- ★ D. Directly proportional



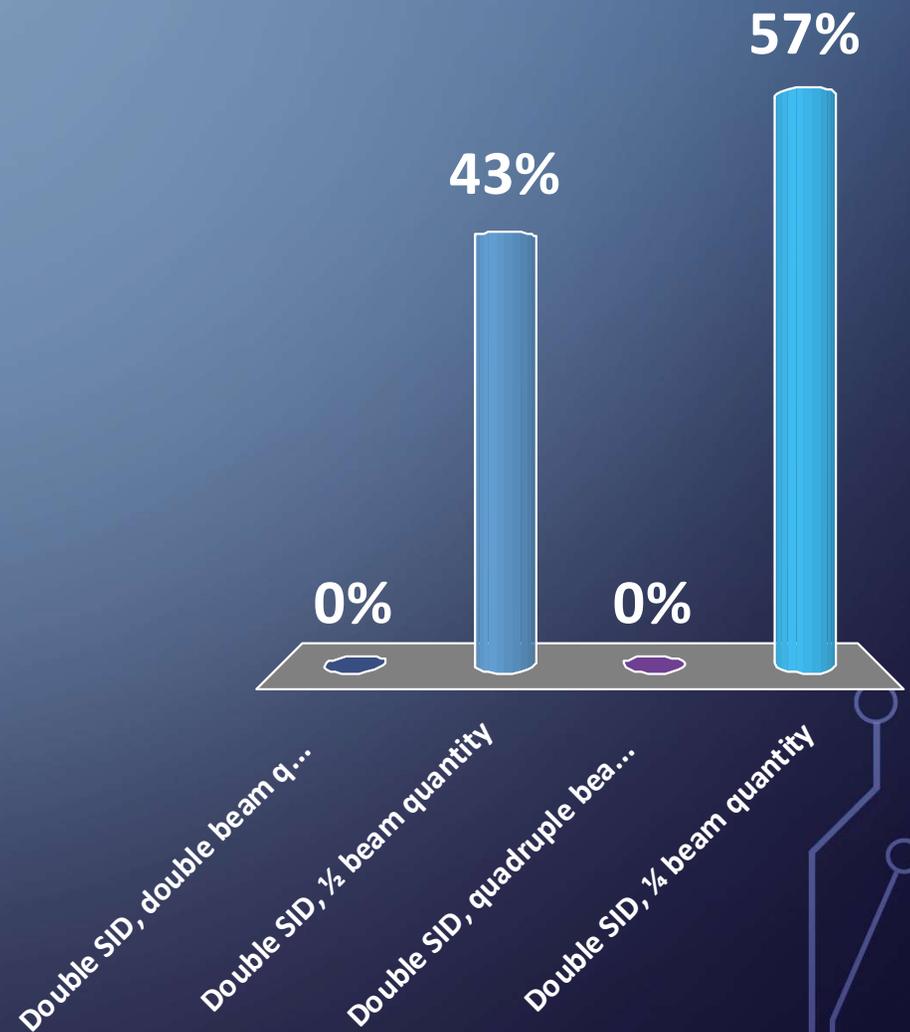
INCREASING KVP BY _____ RESULTS IN THE SAME CHANGE TO RECEPTOR EXPOSURE AS DOUBLING THE MAS.

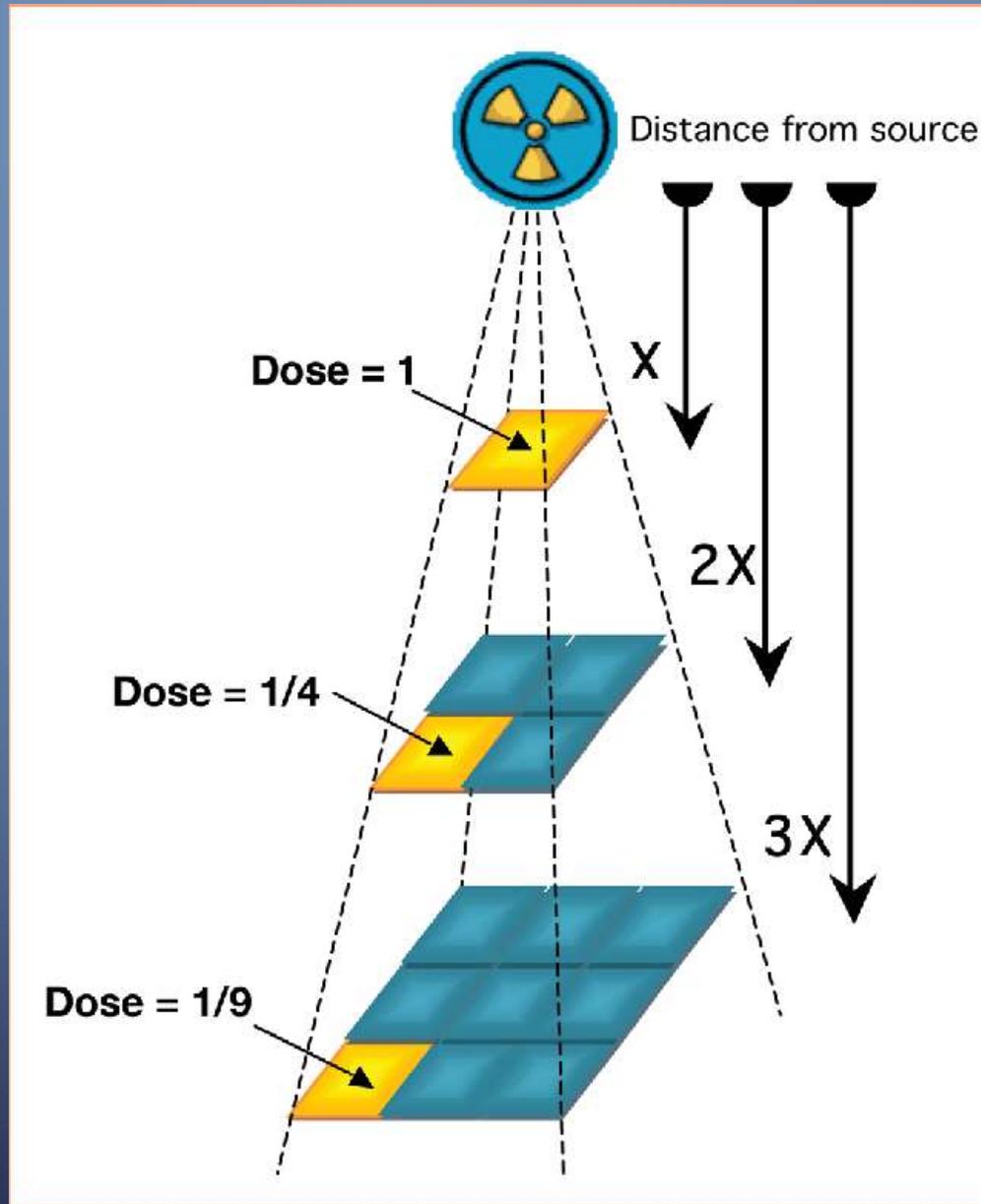
- A. 10%
- ★ B. 15%
- C. 20%
- D. 50%



WHICH OF THE FOLLOWING STATEMENTS BEST REPRESENTS THE RELATIONSHIP BETWEEN SID AND BEAM QUANTITY?

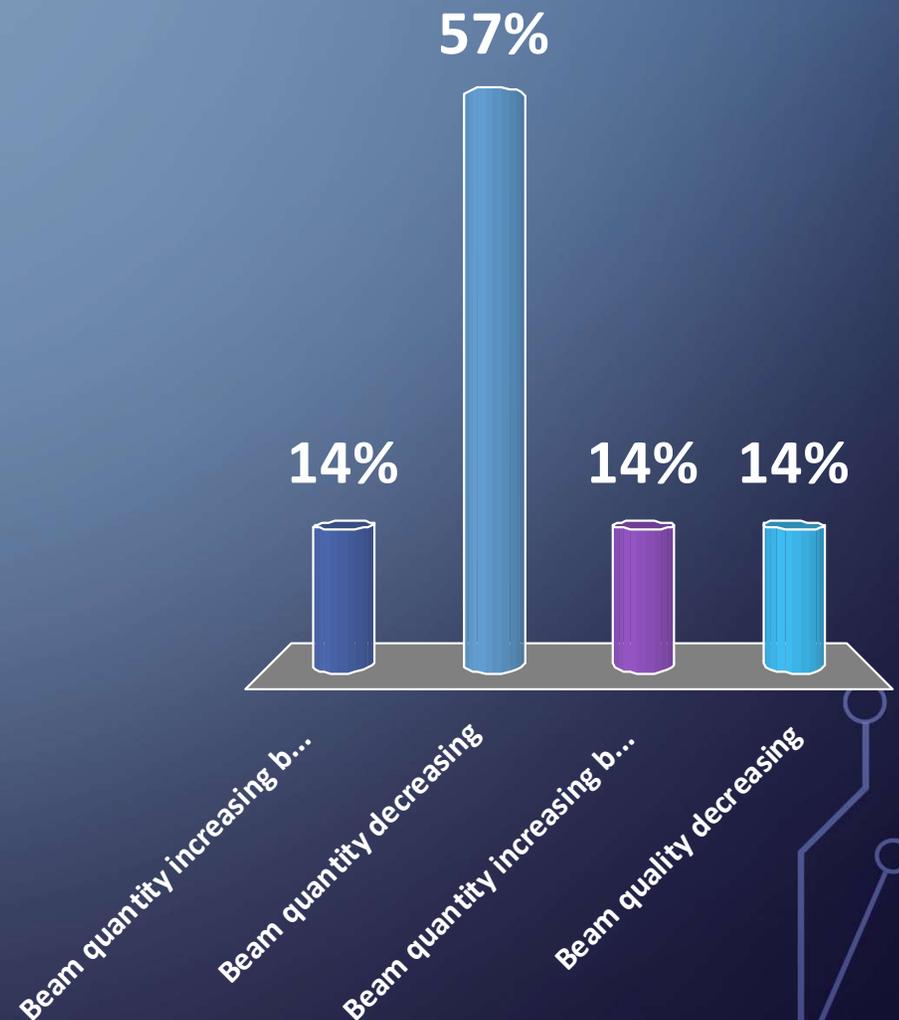
- A. Double SID, double beam quantity
- B. Double SID, $\frac{1}{2}$ beam quantity
- C. Double SID, quadruple beam quantity
- ★ D. Double SID, $\frac{1}{4}$ beam quantity





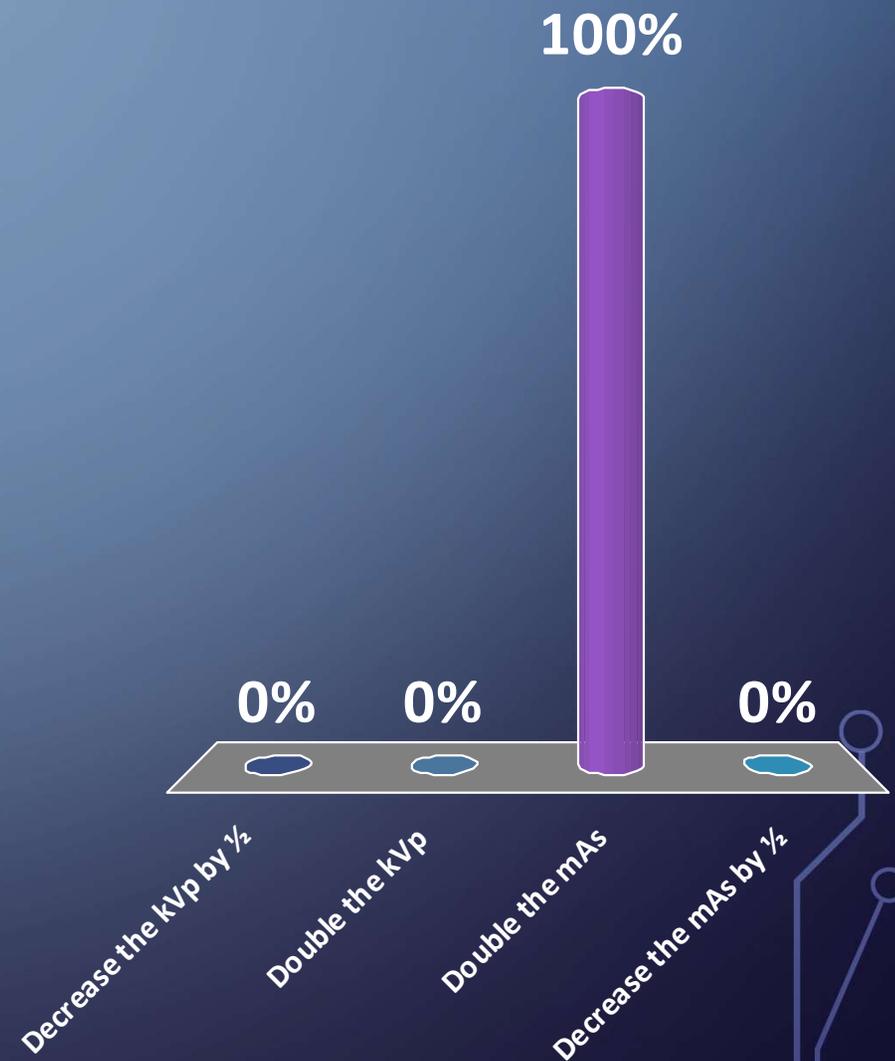
ADDING 2 MM ALUMINUM FILTRATION WILL RESULT IN:

- A. Beam quantity increasing by 50%
-  B. Beam quantity decreasing
- C. Beam quantity increasing by 25%
- D. Beam quality decreasing



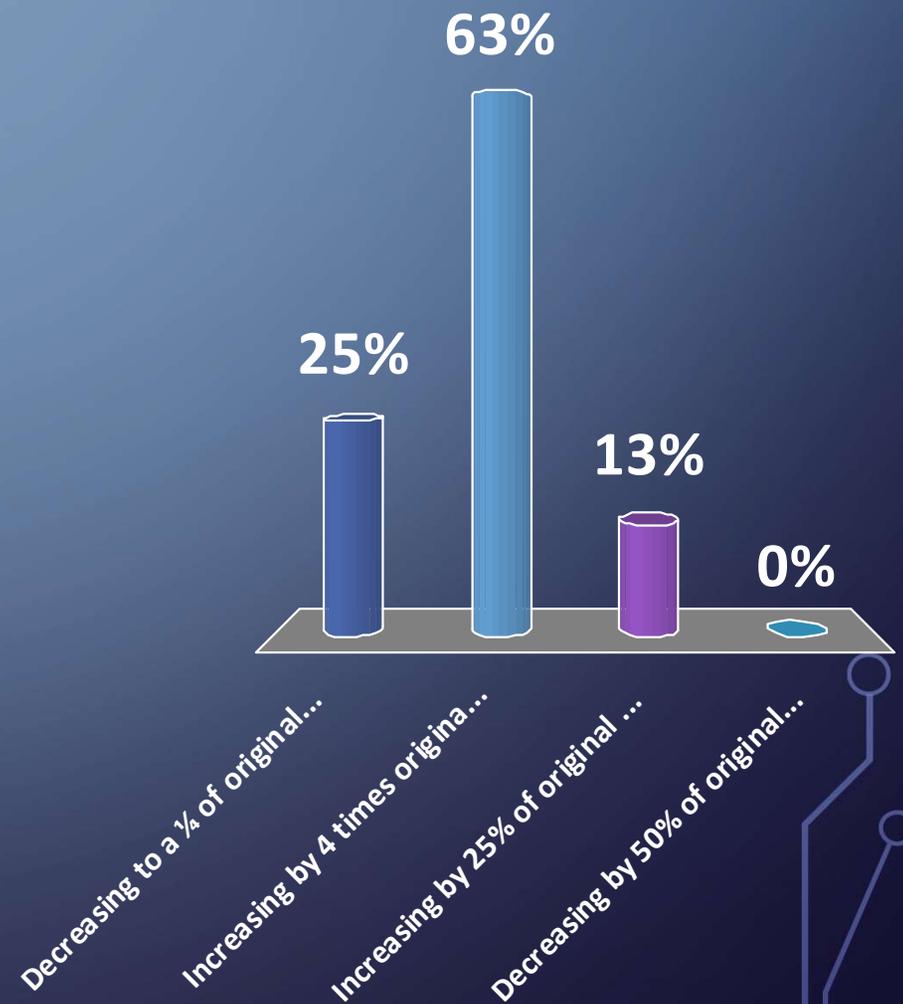
WHICH OF THE FOLLOWING WOULD DOUBLE BEAM QUANTITY?

- A. Decrease the kVp by $\frac{1}{2}$
- B. Double the kVp
- ★ C. Double the mAs
- D. Decrease the mAs by $\frac{1}{2}$



HALVING THE DISTANCE RESULTS IN QUANTITY:

- A. Decreasing to a $\frac{1}{4}$ of original intensity
- ★ B. Increasing by 4 times original intensity
- C. Increasing by 25% of original intensity
- D. Decreasing by 50% of original intensity



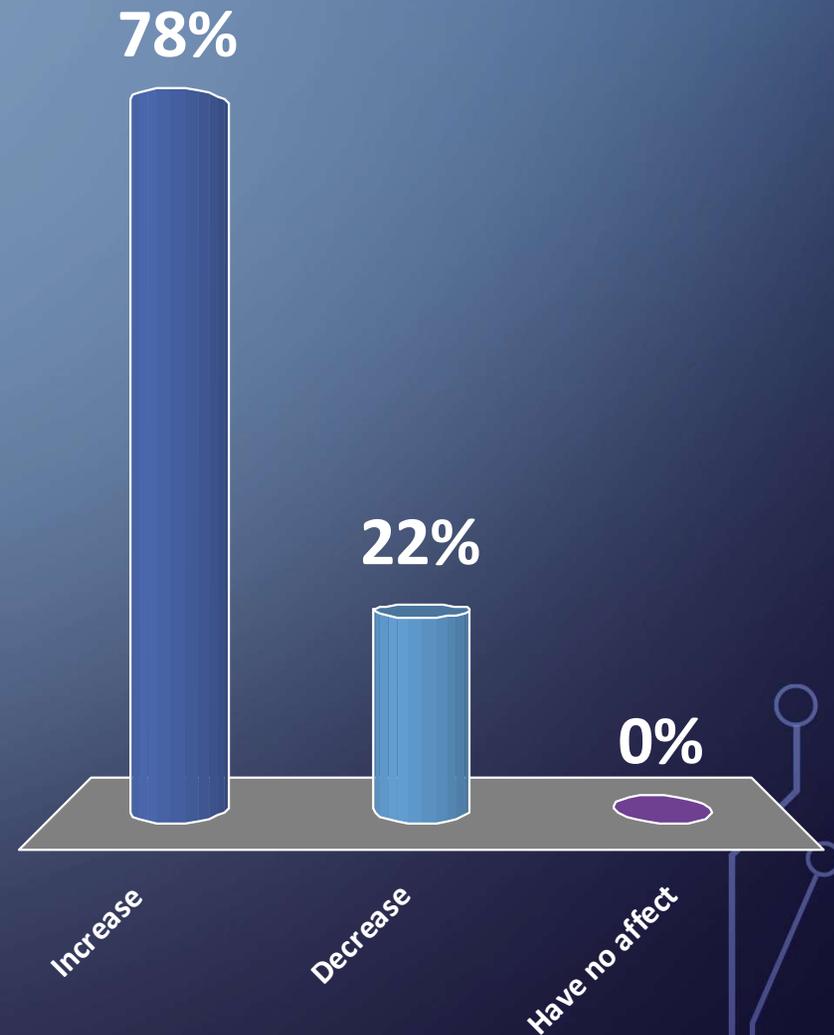
BEAM QUALITY

- #5 - Identify two factors that influence beam quality.
- Explain the relationships that exist between the factors and beam quality.

kVp
Filtration

ADDING FILTRATION WILL ____ BEAM QUALITY.

- ★ A. Increase
- B. Decrease
- C. Have no affect

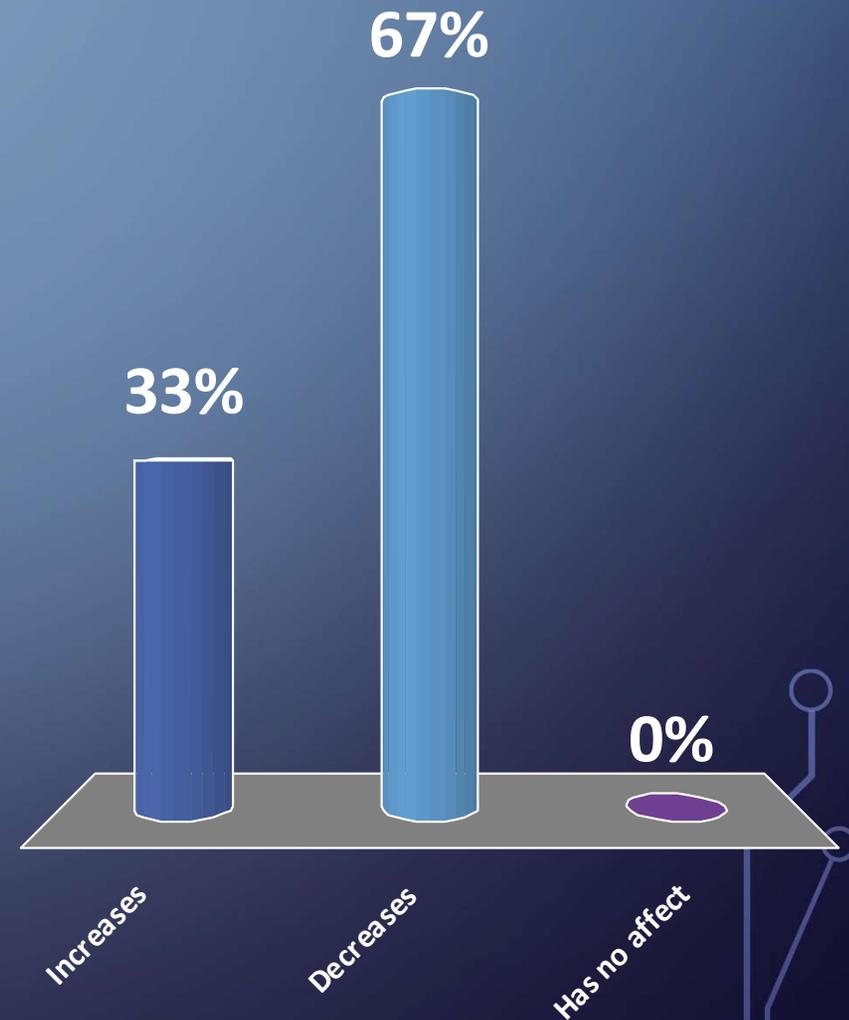


DECREASING KVP, _____ BEAM QUALITY.

A. Increases

★ B. Decreases

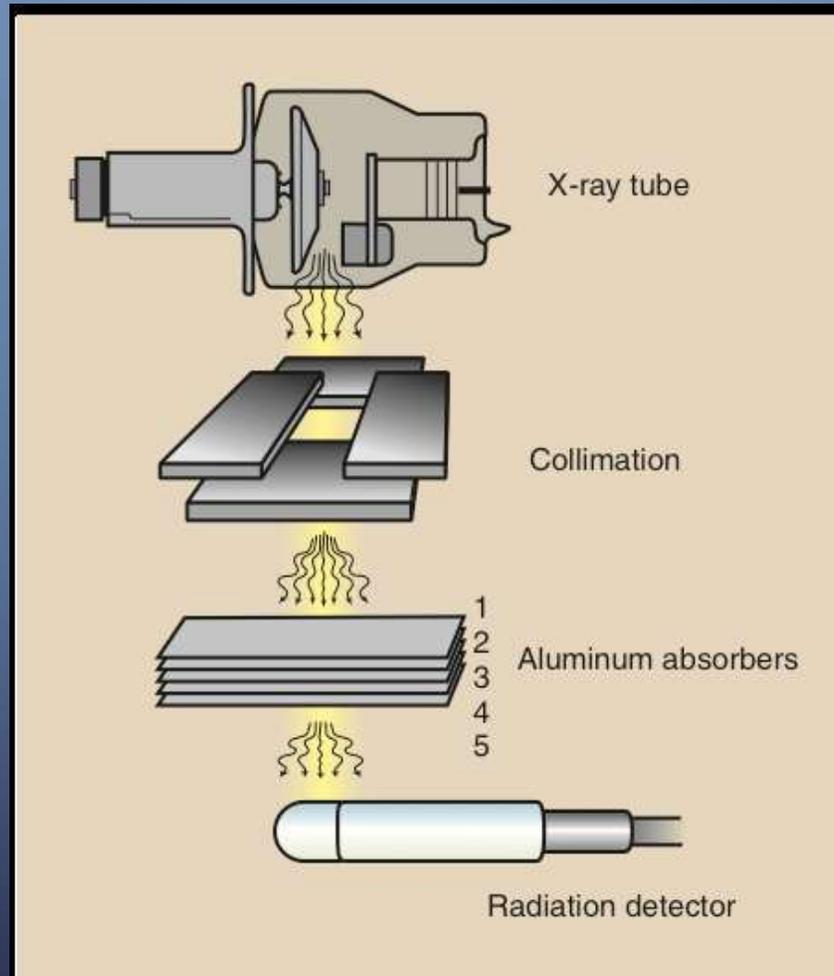
C. Has no affect



	Beam Quantity	Beam Quality
Decrease mAs	decrease	no effect
Increase kVp	increase	increase
Decrease Distance	increase	no effect
Increase Filtration	decrease	increase

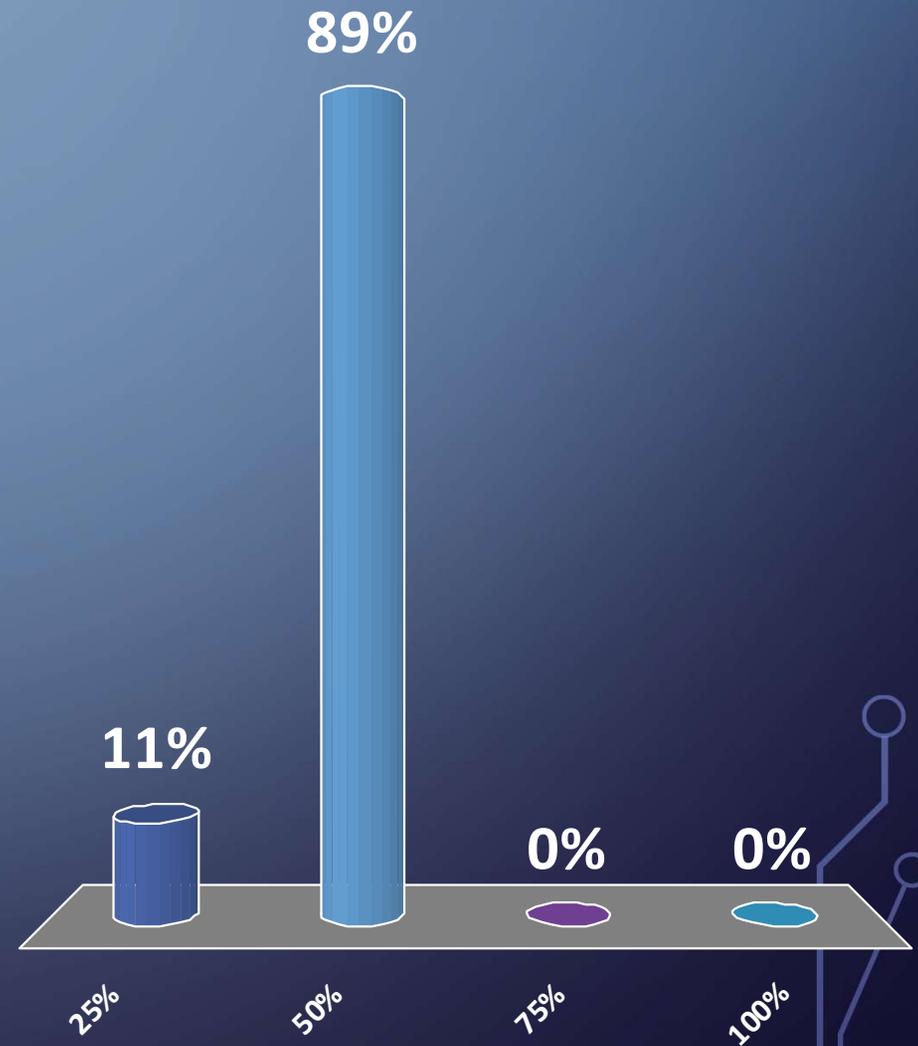
HVL

#6 - Define HVL.



1 HVL WILL REDUCE THE ORIGINAL INTENSITY BY:

- A. 25%
- ★ B. 50%
- C. 75%
- D. 100%



HVL

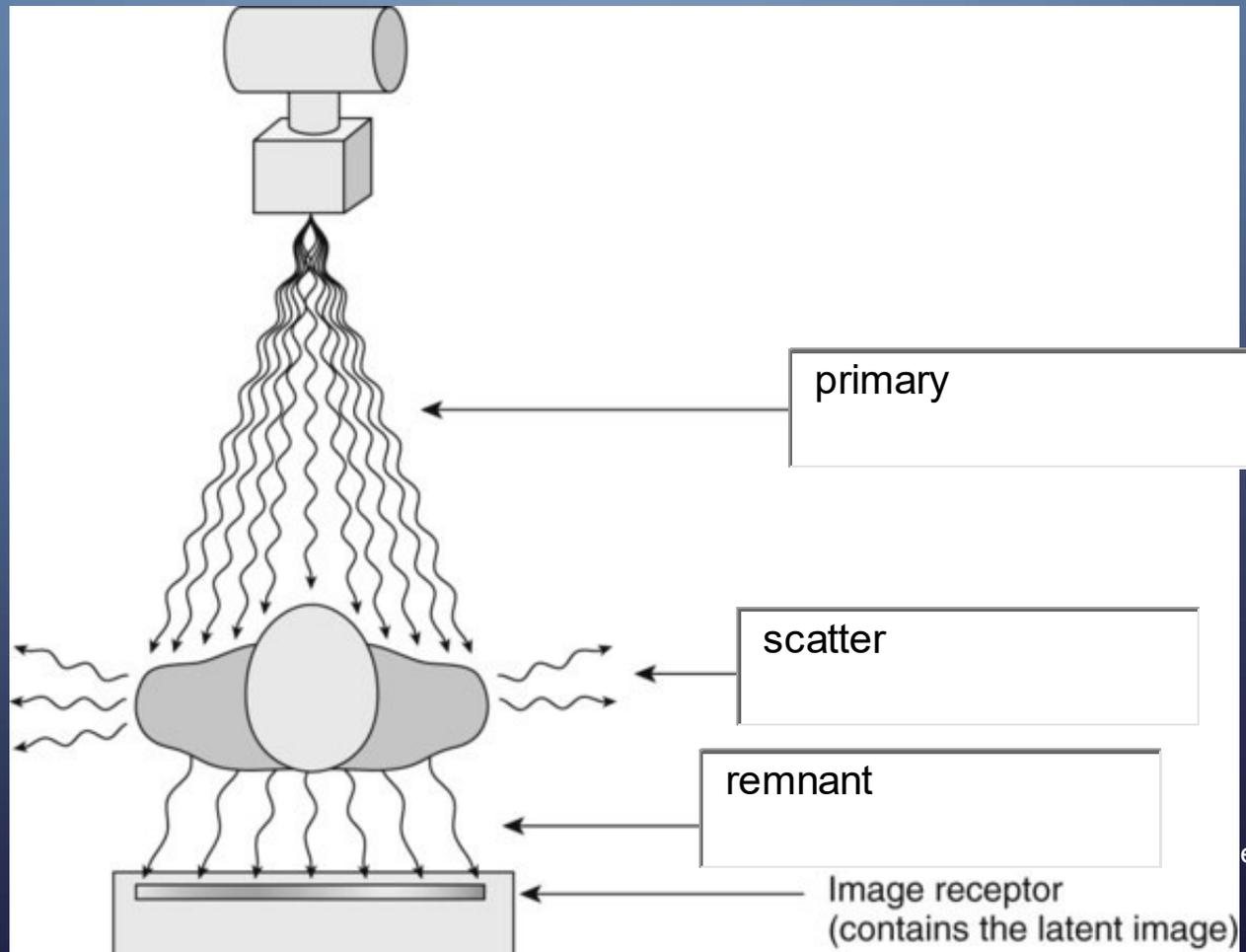
How many HVL's would it take to reduce the intensity of a beam from 50 mGy to an intensity of less than 4 mGy?

HVL

How many HVL's would it take to reduce the intensity of a beam from 80 mGy to an intensity of 10 mGy?

PRIMARY VS REMNANT BEAM

#7 - Differentiate between the primary and remnant beam.



EMISSION SPECTRUM

#8 - Explain what an emission spectrum represents. Explain the difference between the discrete and continuous emission spectrum.

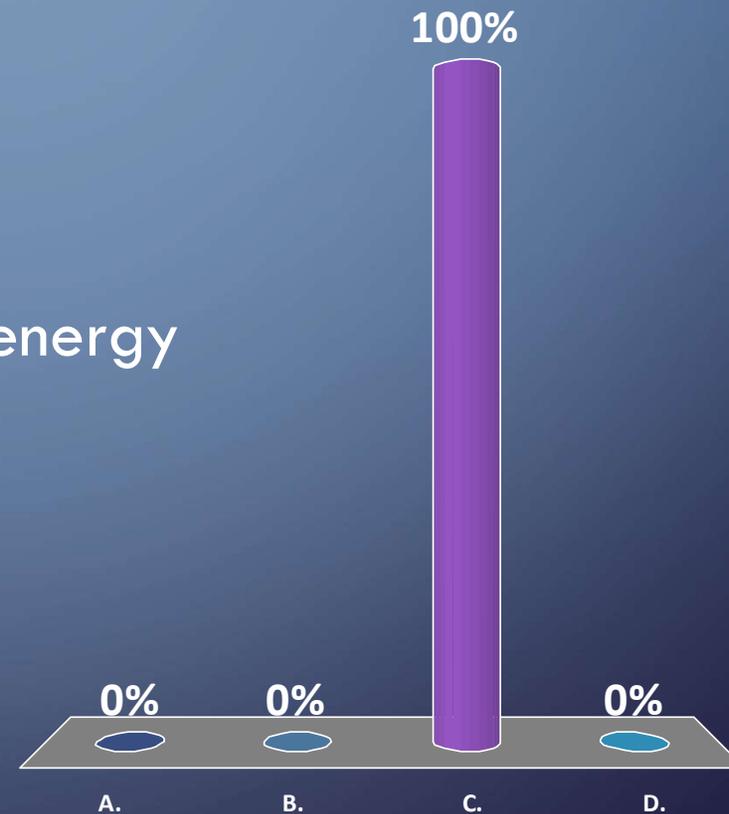
X-RAY EMISSION SPECTRUM PLOTS:

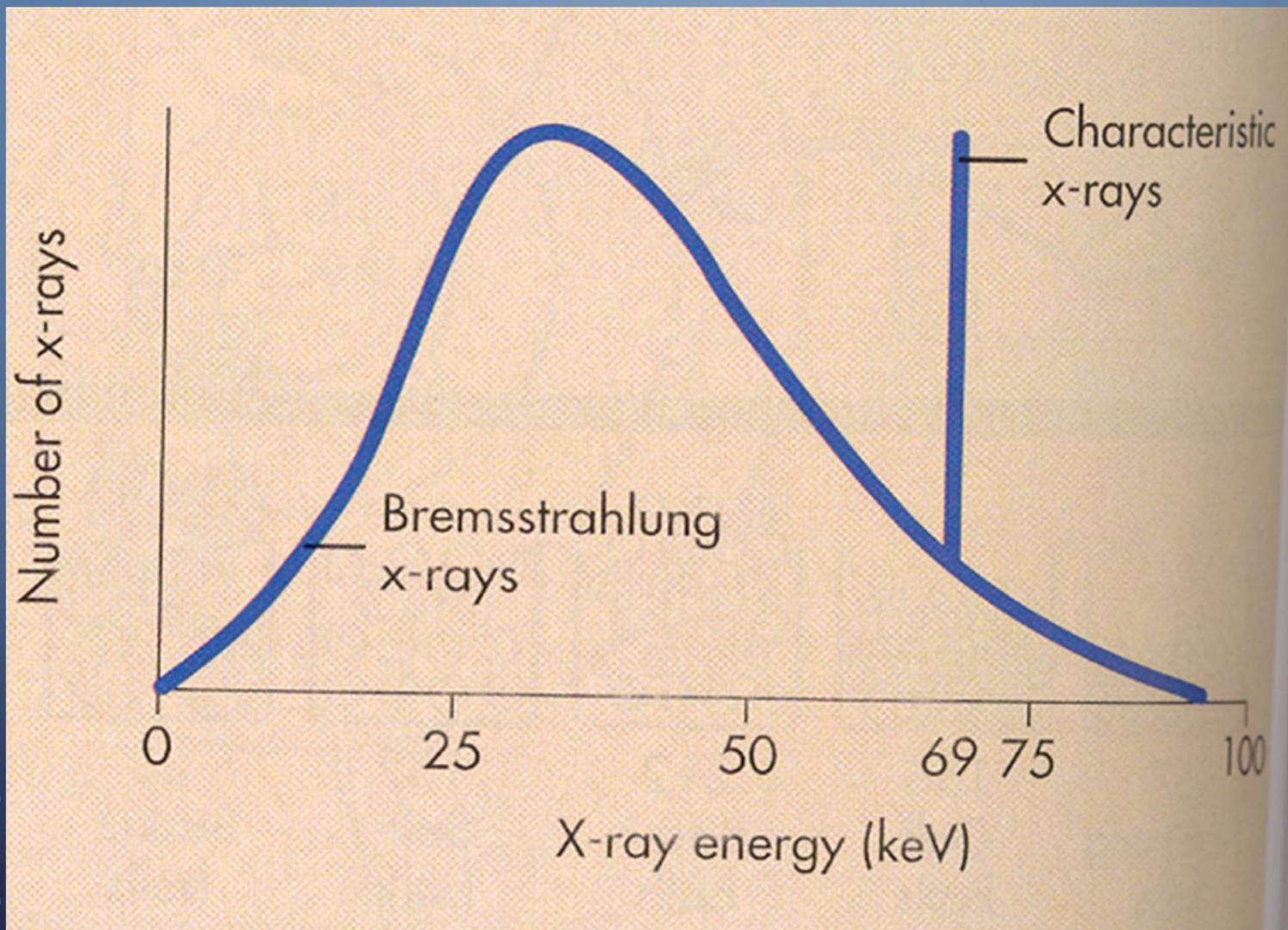
A. Amplitude vs quality

B. mAs vs kVp

★ C. Number of x-rays versus energy

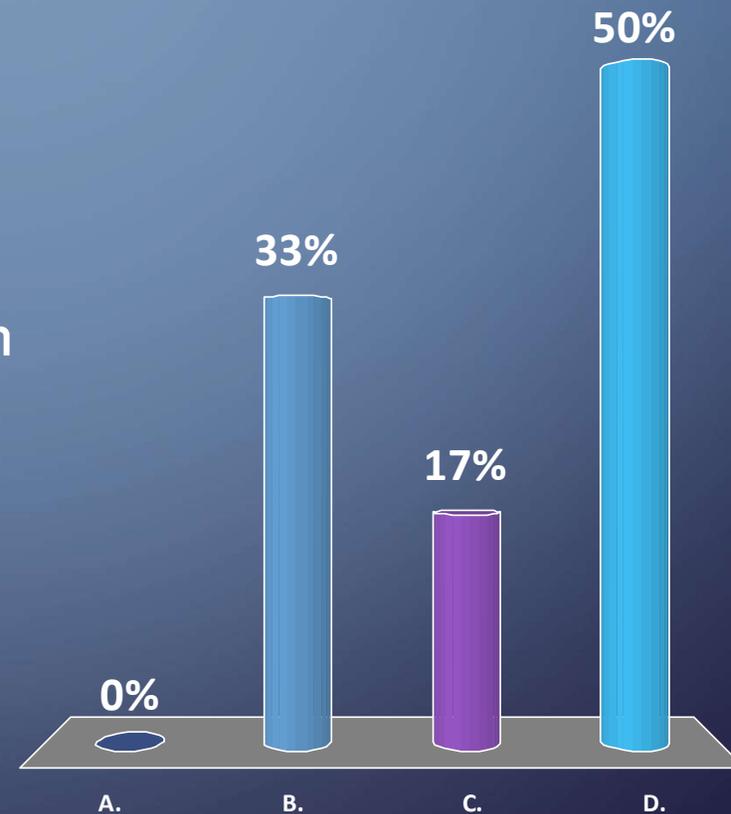
D. mAs vs energy



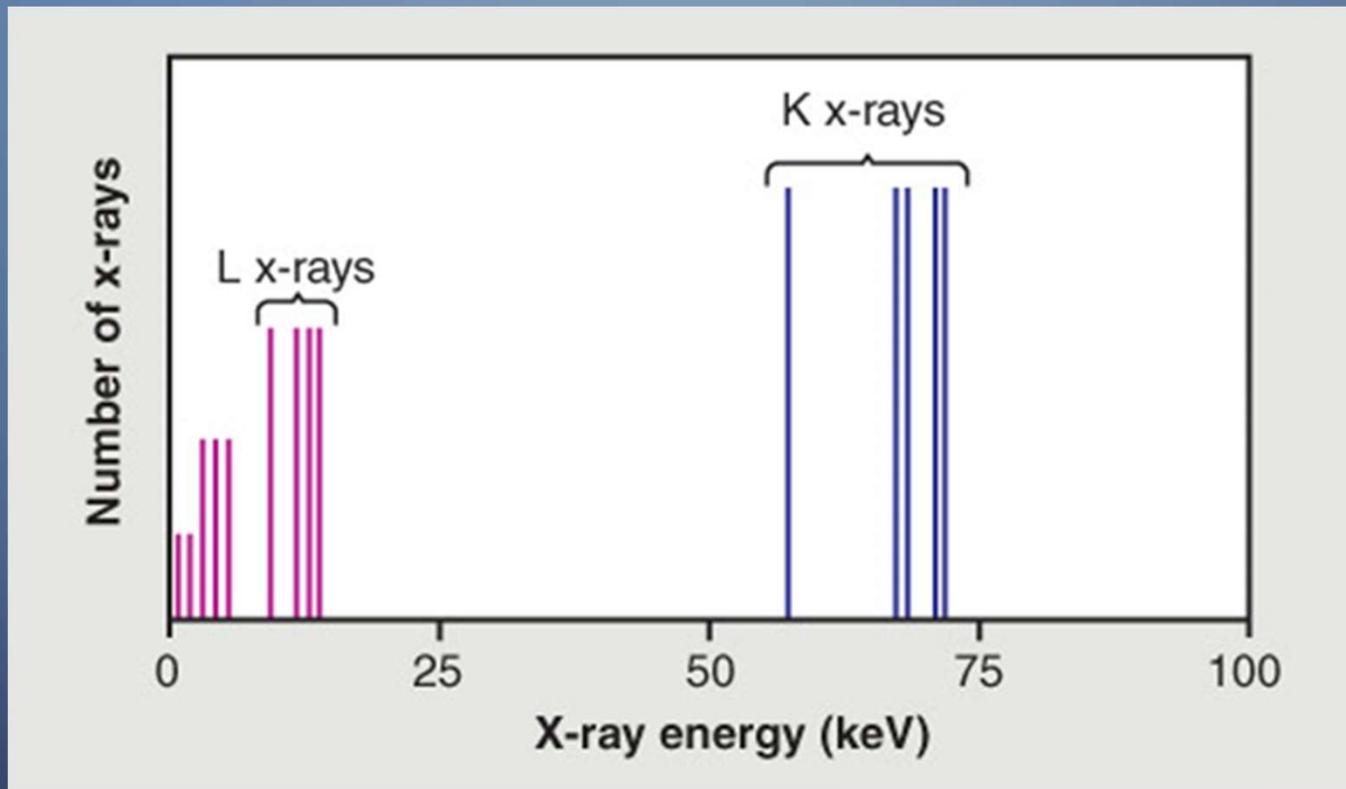


THE CHARACTERISTIC SPECTRUM IS DESCRIBED AS:

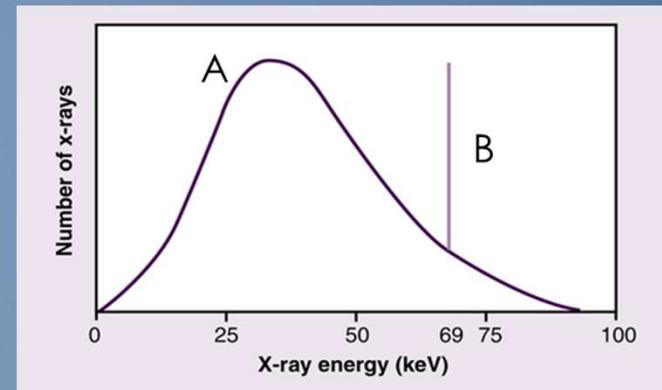
- A. A continuous spectrum
- ★ B. A discrete spectrum
- C. A heterogeneous spectrum
- D. Both A and C



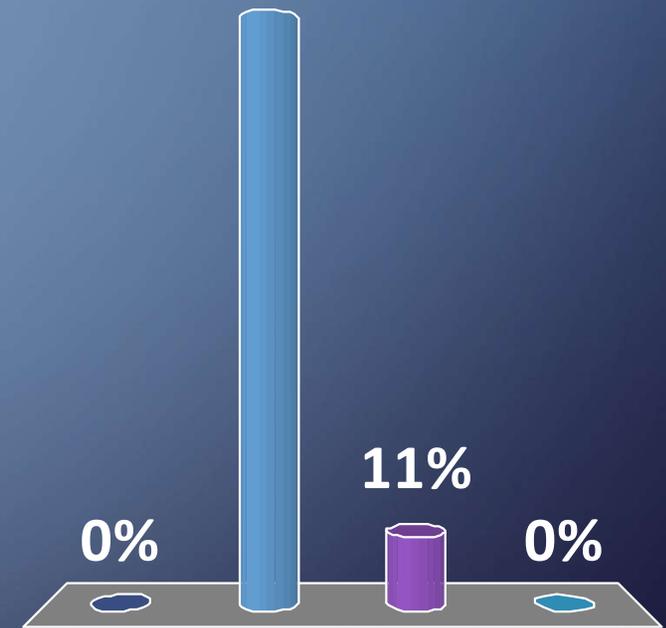
DISCRETE EMISSION SPECTRUM (CHARACTERISTIC)



LETTER 'A' REPRESENTS?



89%



- A. Characteristic photons/Discrete spectrum
- ★ B. Brems photons/continuous spectrum
- C. Brems photons/Discrete spectrum
- D. Characteristic photons/Continuous spectrum

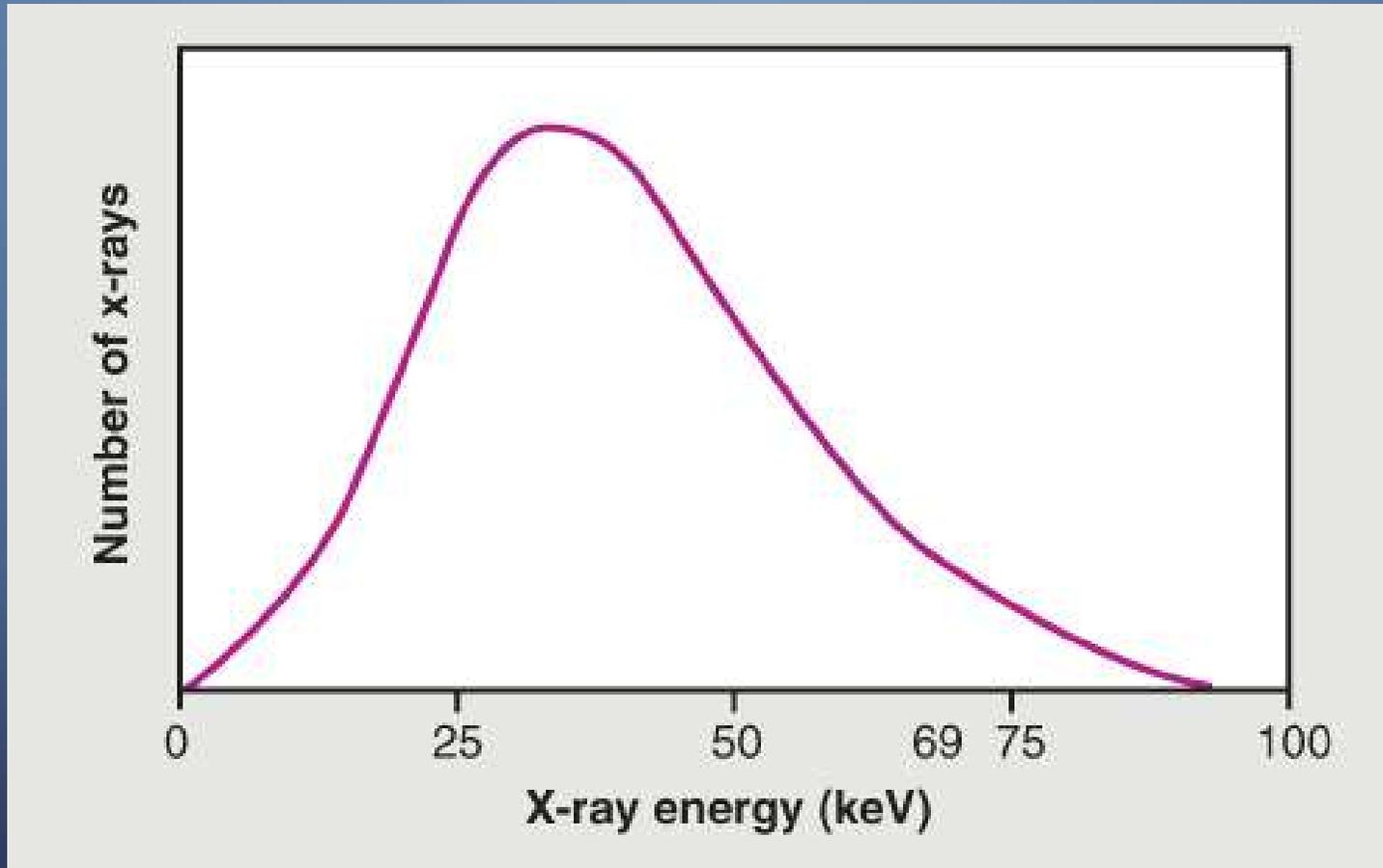
Characteristic photons/D...

Brems photons/continuo...

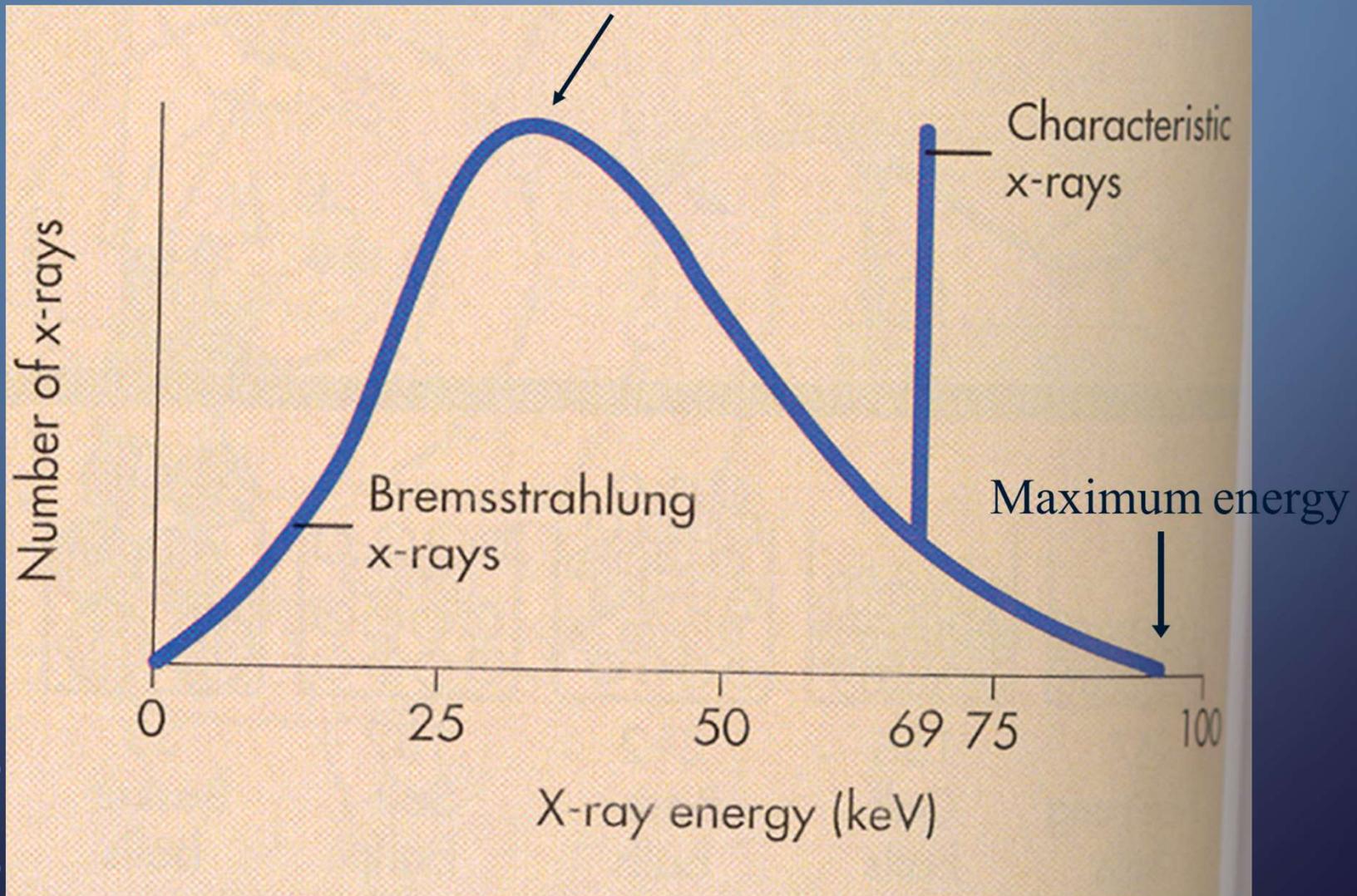
Brems photons/Discrete ...

Characteristic photons/ ...

CONTINUOUS EMISSION SPECTRUM (BREMSSTRAHLUNG)



Average energy



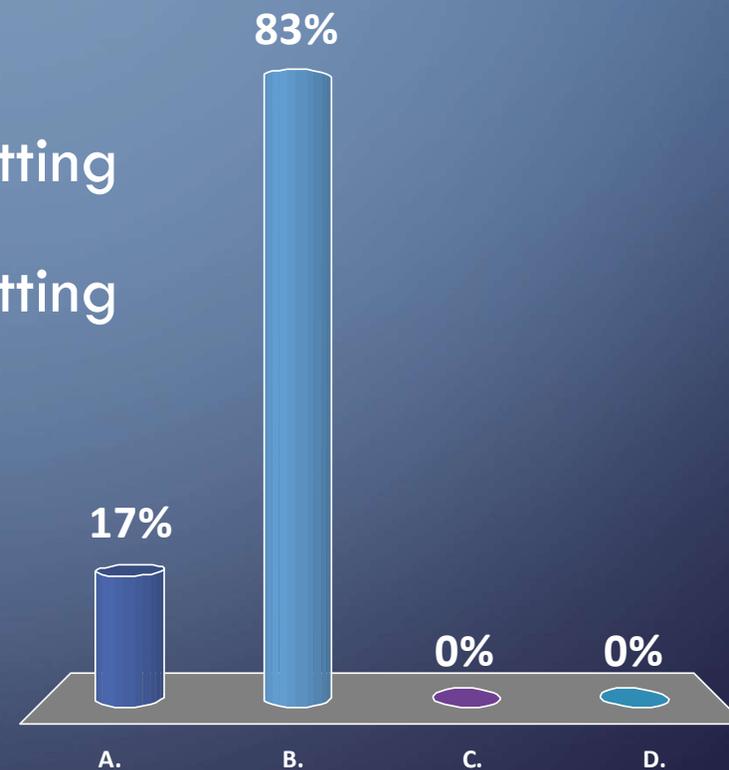
THE MAJORITY OF PHOTONS HAVE AN ENERGY EQUAL TO:

A. The kVp setting

★ B. About 30% of the kVp setting

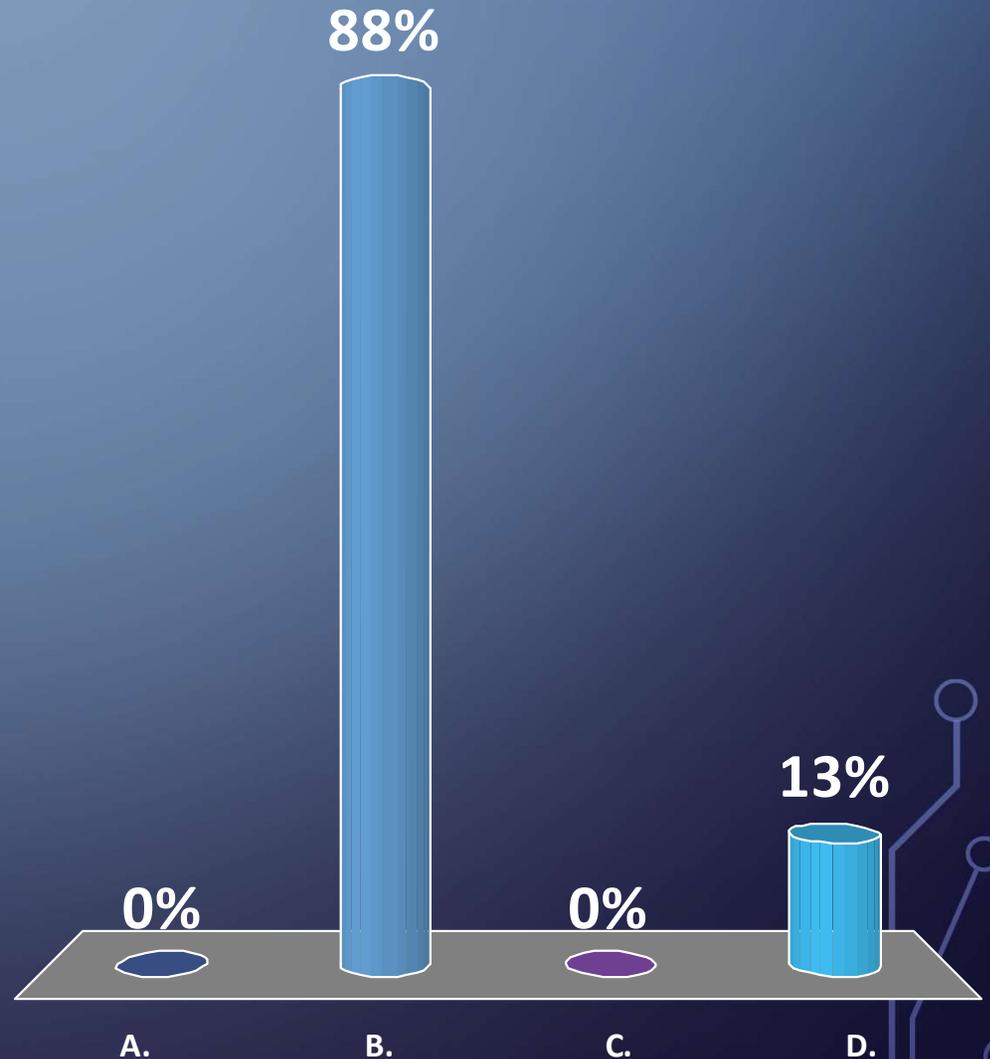
C. About 50% of the kVp setting

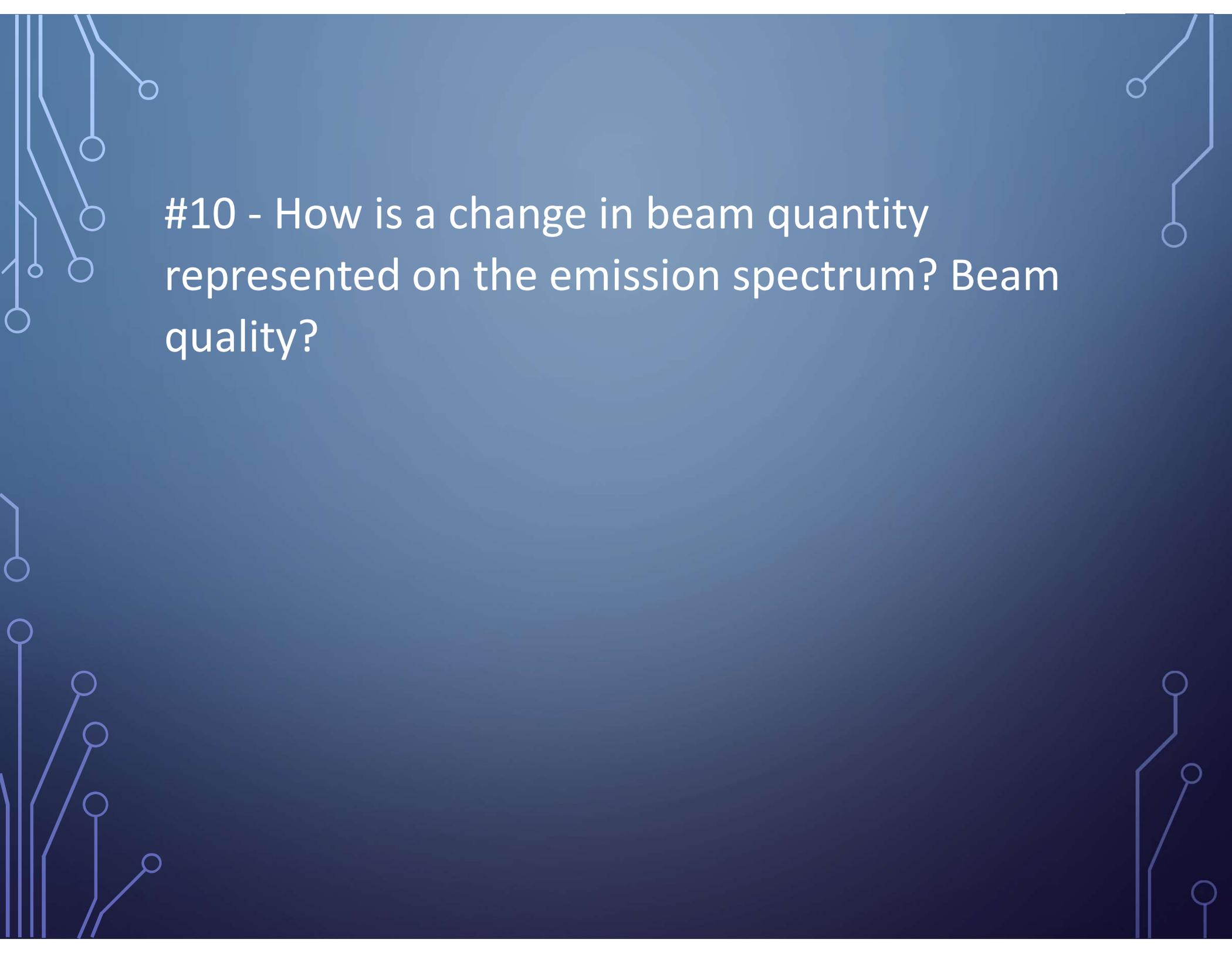
D. It depends on the mAs



IN A TYPICAL X-RAY TUBE OPERATED AT 90 KVP, THE MOST ABUNDANT X-RAY PRODUCED WOULD BE:

- A. 10 keV brems
- ★ B. 30 keV brems
- C. 12 keV characteristic
- D. 90 keV characteristic



A decorative background pattern of light blue circuit board traces and nodes is visible on a dark blue gradient background. The pattern consists of various lines and circles connected at nodes, resembling a printed circuit board layout.

#10 - How is a change in beam quantity represented on the emission spectrum? Beam quality?

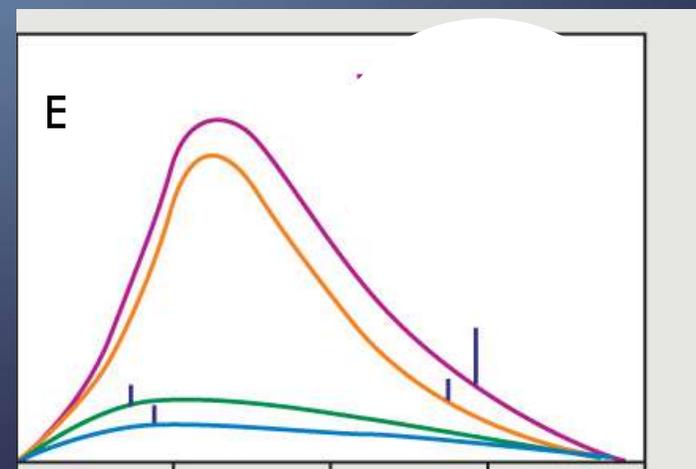
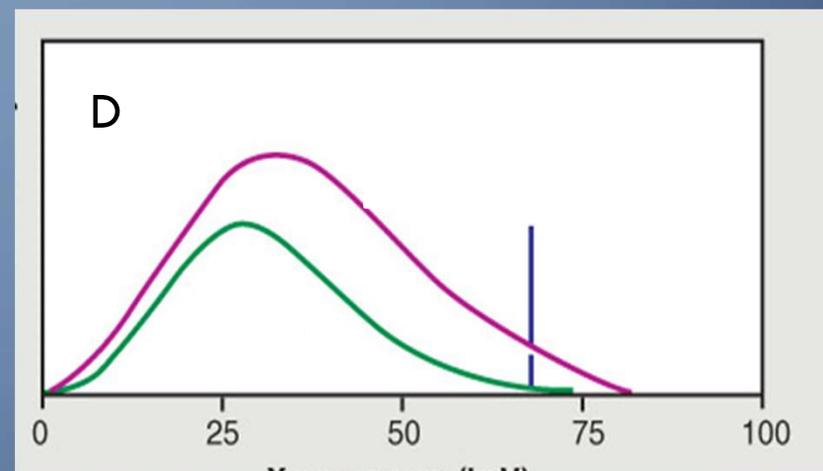
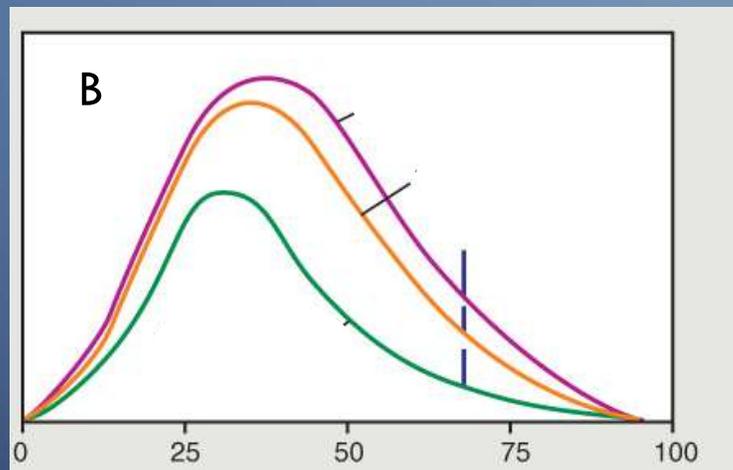
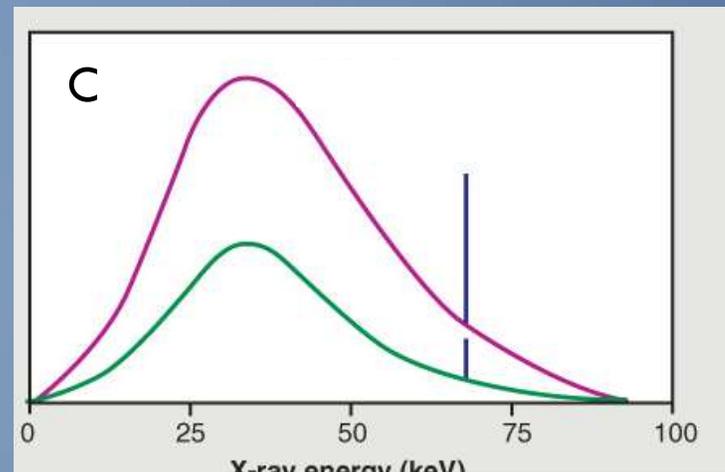
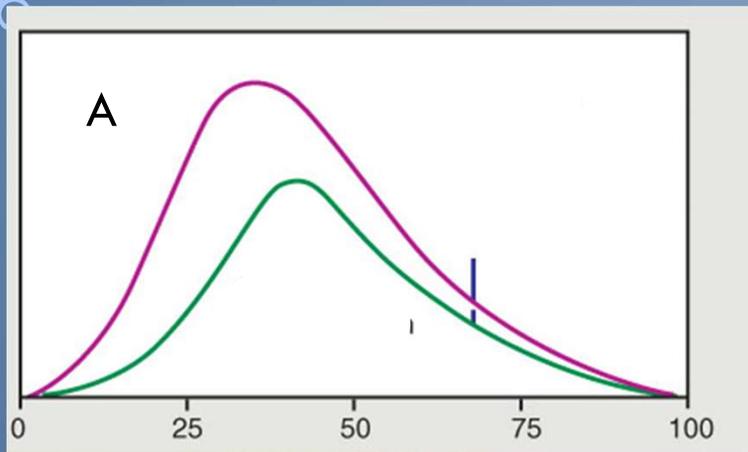
#11 - Explain how an increase in mA will affect the continuous spectrum and discrete spectrum?

#12- Explain how an increase in kVp will affect the continuous spectrum and discrete spectrum?

#13 -Explain how a decrease in filtration will affect the continuous spectrum and discrete spectrum?

#14 - Explain how an increase in target material atomic number will affect the continuous spectrum and discrete spectrum?

#15 - Explain how changing from single phase to three phase will affect the continuous spectrum and discrete spectrum?



Identify the change that took place (mAs, kVp, Filtration, Target material or Generator) that resulted in the changes of the emission spectrums represented as A – E

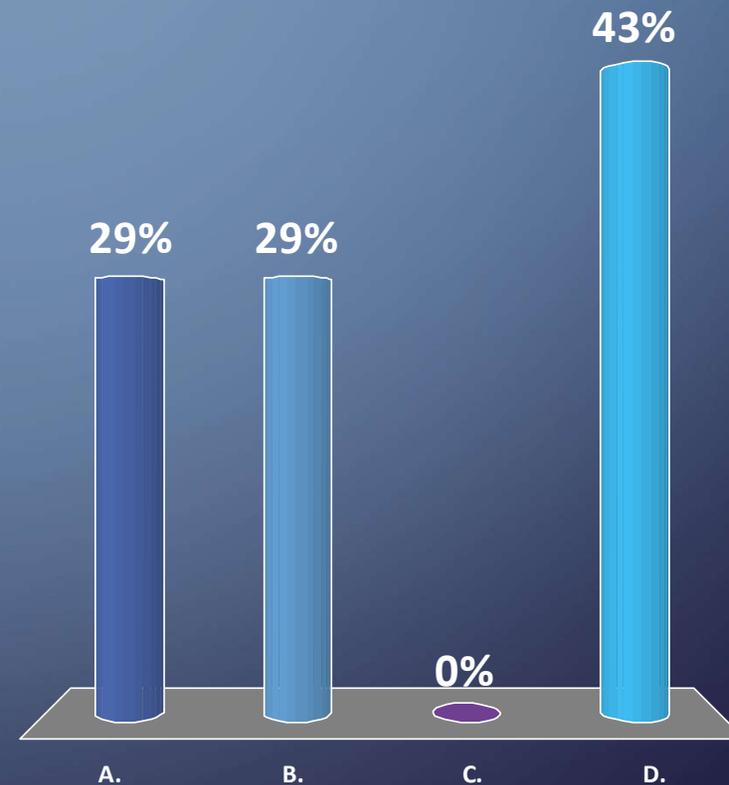
THE CHARACTERISTIC X-RAY ENERGY LEVEL IS AFFECTED BY:

A. kVp

B. mAs

C. Added Filtration

★ D. Target material



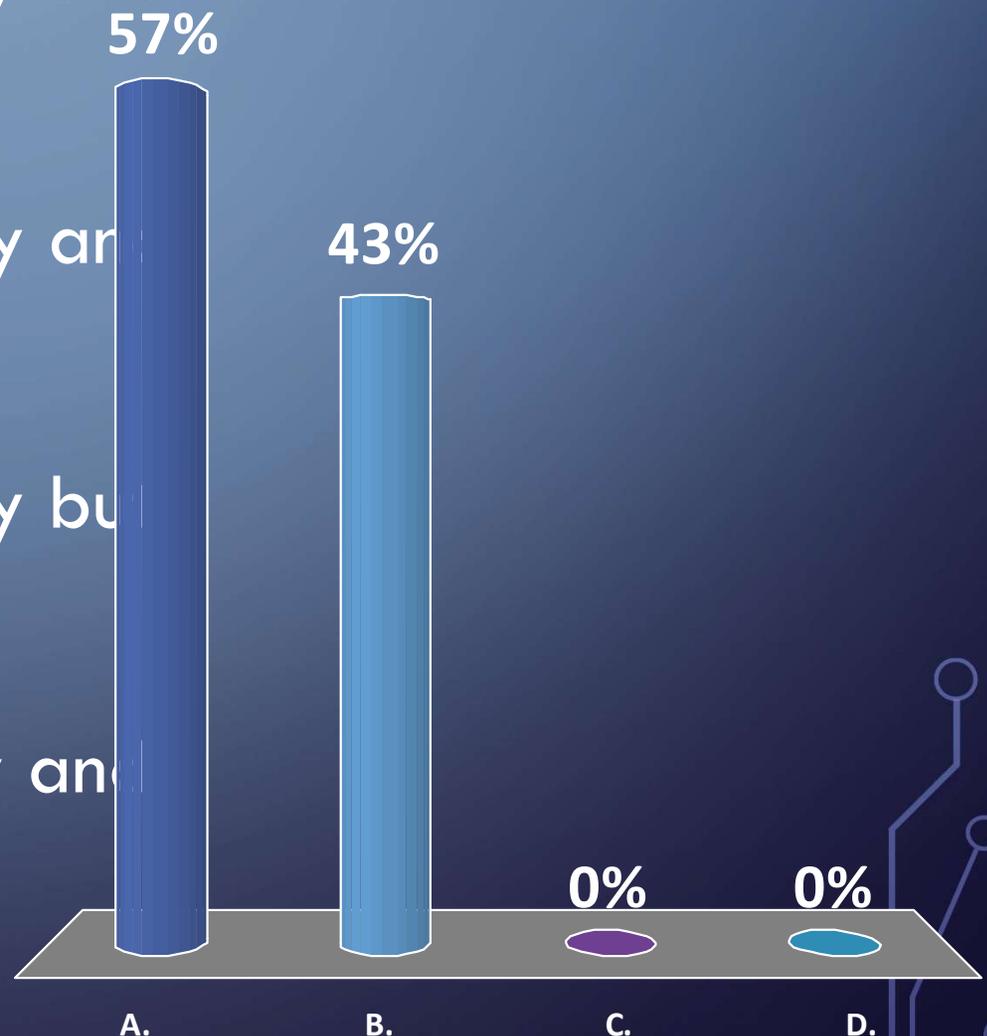
CHANGING FROM A 3 PHASE TO A SINGLE PHASE GENERATOR WILL CAUSE:

 A. A decrease in quantity and quality

B. An increase in quantity and quality

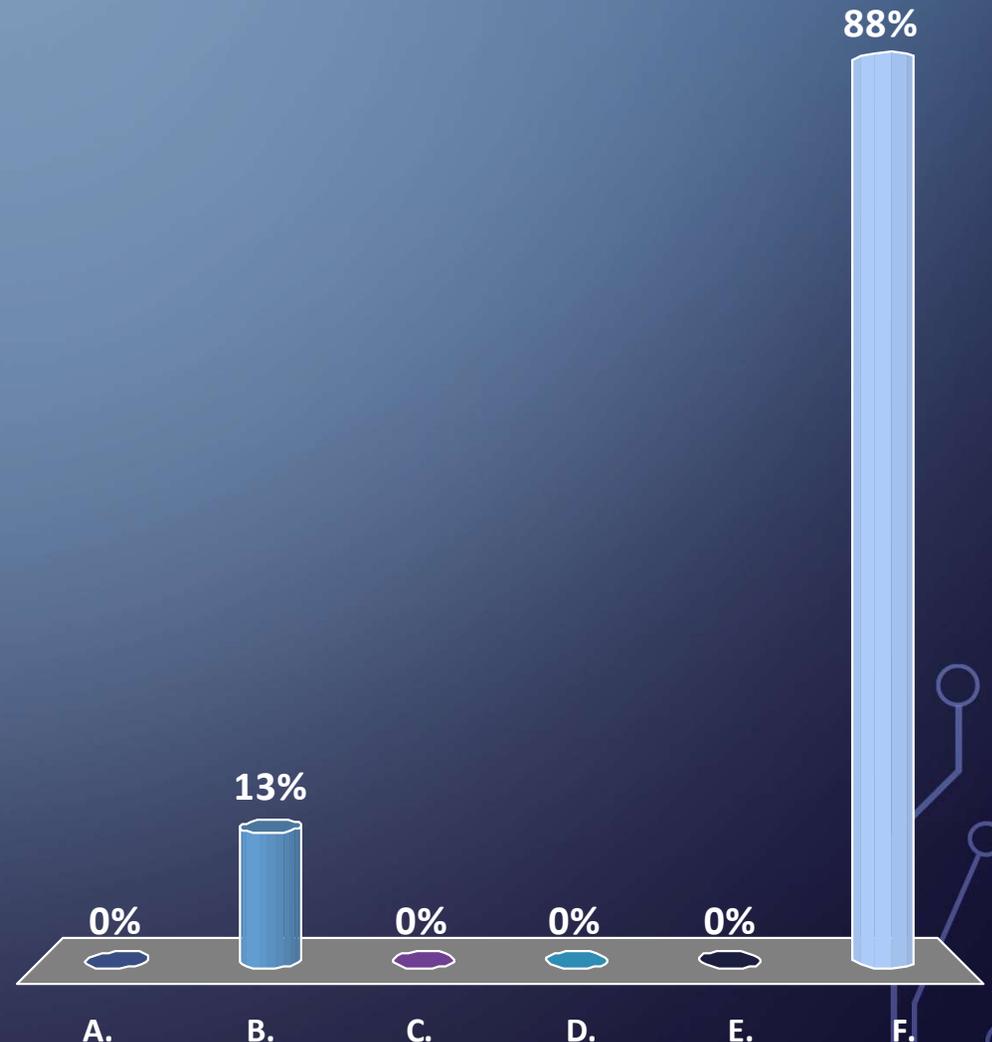
C. An increase in quantity but a decrease in quality

D. No change in quantity and quality

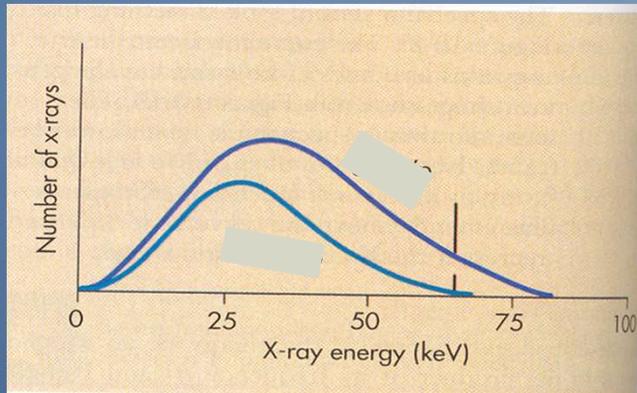


INCREASING THE KVP WILL AFFECT THE BREMS EMISSION SPECTRUM BY:

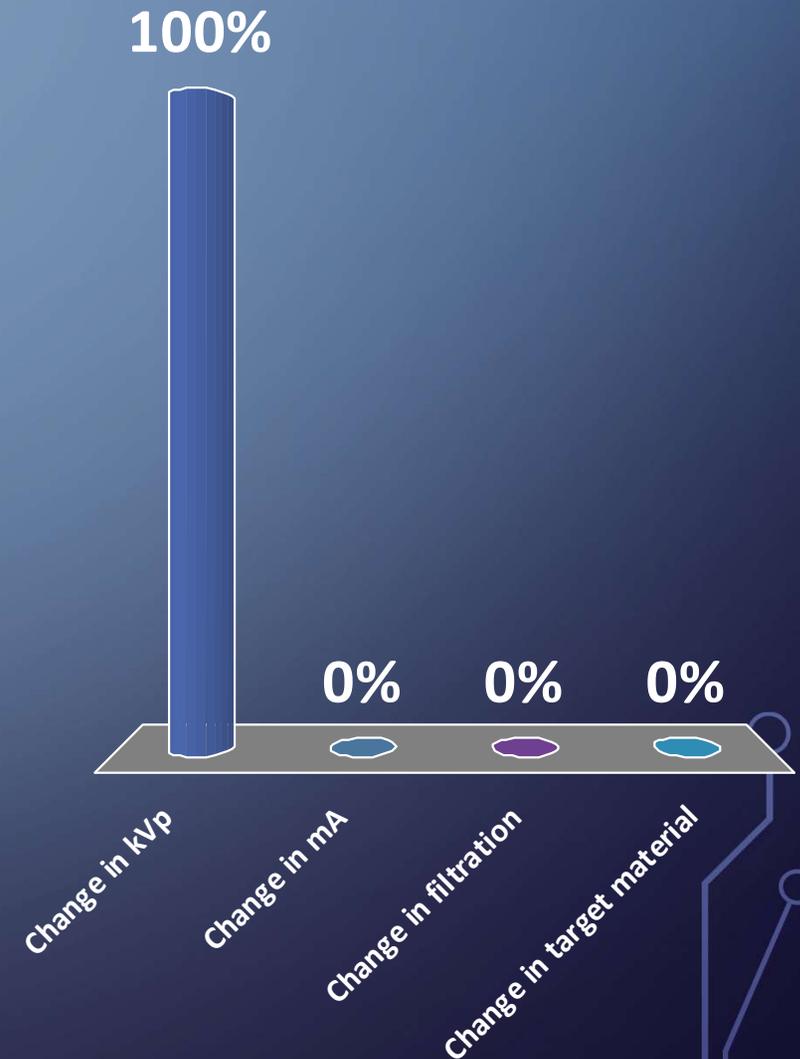
- A. Decreasing the amplitude
- B. Increasing the amplitude
- C. Shifting it to the right
- D. Shifting it to the left
- E. Both A and D
- ★ F. Both B and C



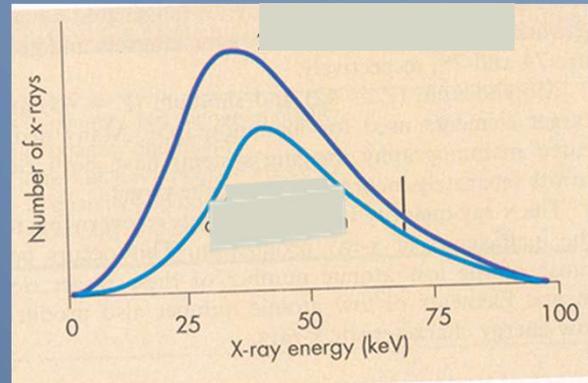
WHAT IS THE MOST LIKELY CAUSE OF THE CHANGE IN THE EMISSION SPECTRUM REPRESENTED BY THE CHART BELOW?



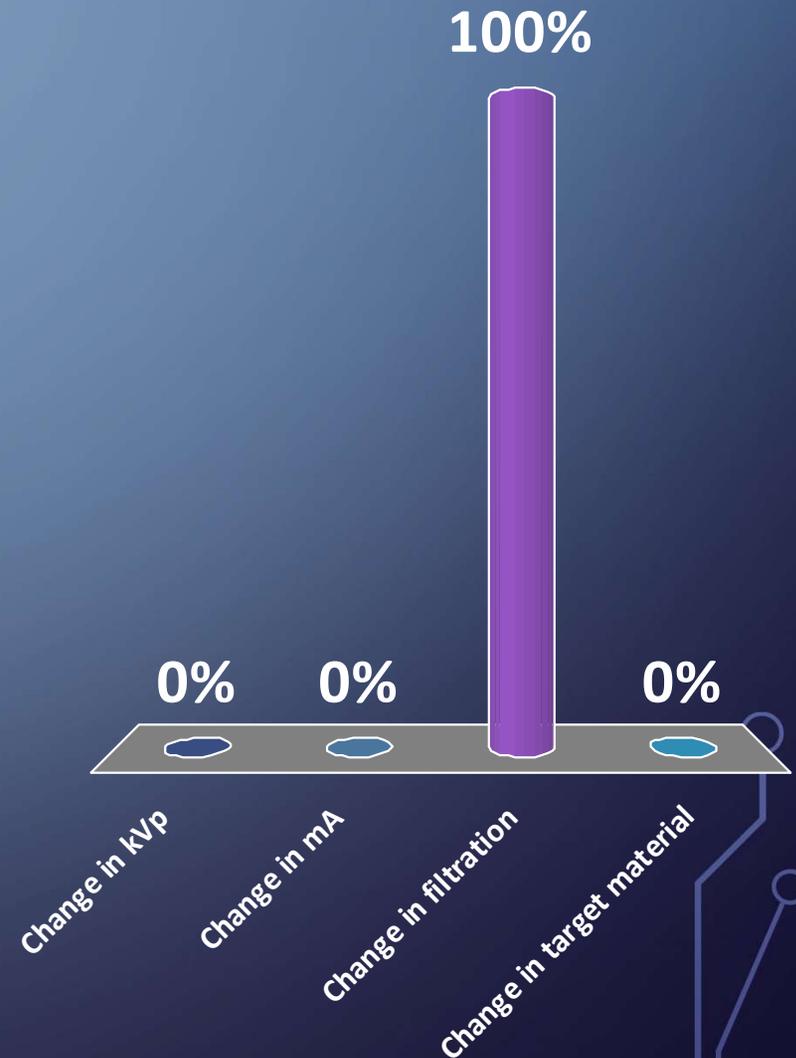
- ★ A. Change in kVp
- B. Change in mA
- C. Change in filtration
- D. Change in target material



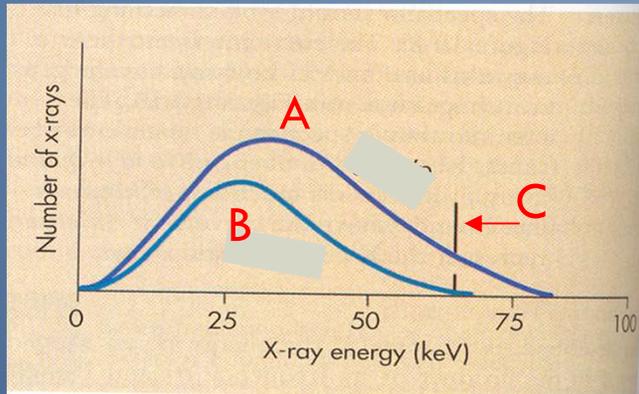
WHAT IS THE MOST LIKELY CAUSE OF THE CHANGE IN THE EMISSION SPECTRUM REPRESENTED BY THE CHART BELOW?



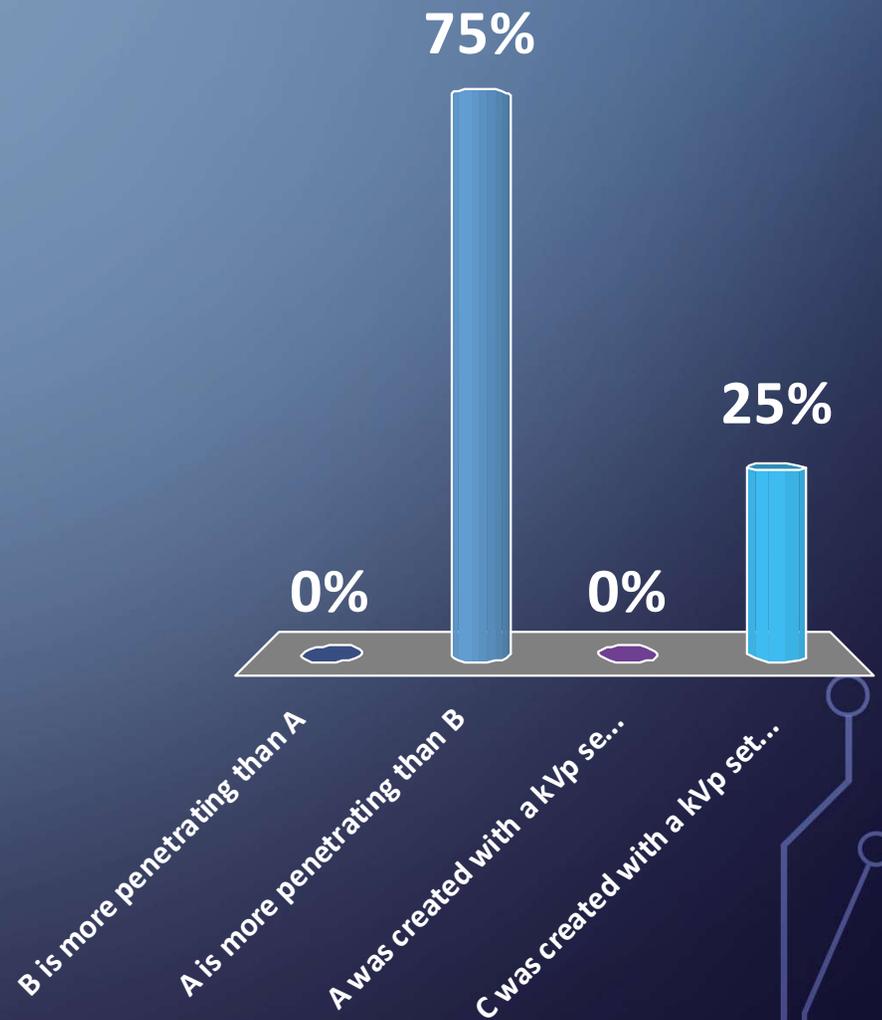
- A. Change in kVp
- B. Change in mA
- C. Change in filtration
- D. Change in target material



WHICH OF THE STATEMENTS BELOW IS ACCURATE?



- A. B is more penetrating than A
- ★ B. A is more penetrating than B
- C. A was created with a kVp setting of 30
- D. C was created with a kVp setting of 69



SUMMARY

Factors Affecting Emission Spectrum

Increase (Improvement) In	Effect on Quantity	Effect on Quality
mA	inc	no
kVp	inc	inc
Tube filtration	dec	inc
Generator type	inc	inc
Target material	inc	inc